Abstract

The Relationship between Neuropsychological Measures of Executive Functioning and Anxiety with Neurophysiological Markers of Cognitive and Affective Control

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With cognitive behavior therapy (CBT) centrally positioned as the dominant model in the psychosocial treatment of mental disorders, research investigating biomarkers of dysfunctional cognitive processing may aid our understanding of the neurobiological basis of these disorders and assist in formulating integrated treatments. One event related potential theorized to function in the cognitive control of adaptive behavior, the feedback negativity (FN), shows differences in a variety of psychiatric samples. While the FN is thought to reflect anterior cingulate error monitoring, based on dopaminergic input from the mesolimbic reward pathways, numerous other variables are related to the FN. However, studies investigating the FN commonly utilize positive and negative feedback from gambling tasks, which have been shown to be inherently affected by fallacious reasoning and affective responses. Thus, the previously described differences in the FN could represent attempts to control affective responses and not solely a biomarker of cognitive dysfunction.

A series of four studies were completed to investigate these questions of FN processing and affective responses to tasks. Initial factor analysis of personality and reward related behavior measures identified a tripartite division in higher order personality indicative of behavioral tendencies toward seeking rewards, behavioral suppression, or maintaining current behaviors. Secondly, creation and validation of a task design of gambling and pattern learning tasks with nearly identical reward feedback found differences in FN and heart rate variability (HRV) responses to the tasks, supporting greater

affective responsivity to loss feedback during the gambling task. A larger scale follow-up study discovered that a number of neuropsychological and personality variables significantly predicted FN feedback processing in response to these tasks, generally supporting a bifurcation of attention engagement, with the pattern learning task being more highly related to neurocognitive functioning, while the gambling task was more closely related to affect regulation. Finally, a pilot study comparing normal controls and a Generalized Anxiety Disorder (GAD) sample identified group differences through a behavioral bias to avoid the demonstrated greater affective response to the gambling task in the GAD group, generally supporting use of the FN as a biomarker of perceptual bias in clinical anxiety.

The Relationship between Neuropsychological Measures of Executive Functioning and Anxiety with Neurophysiological Markers of Cognitive and Affective Control

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To my wonderful children: this would never have been completed without the support and patience of Jacy, Haley, Jonathan, Ethan, and Nicholas.

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Chapter 1: Introduction

The Cognitive Model of Mental Illness

The cognitive model and cognitive therapy, either implemented alone or within a combined cognitive and behavior therapy (CBT), focuses largely on how changing maladaptive patterns of thought can lead to changes in affect and improve maladaptive behaviors (Lambert, Bergin, & Garfield, 2004). While this category involves a heterogeneous set of therapeutic interventions, techniques, settings, and modalities, CBT has been shown to be effective in the treatment of many mental illnesses, including anxiety disorders, depressive disorders, psychosis, schizophrenia, substance abuse, eating disorders, and personality disorders (Driessen & Hollon, 2010; Gutierrez, Sanchez, Trujillo, & Sanchez, 2009; Matusiewicz, Hopwood, Banducci, & Lejuez, 2010; Murphy, Straebler, Cooper, & Fairburn, 2010; Otte, 2011; Rathod, Phiri, & Kingdon, 2010). The overall etiological theory of the cognitive model suggests that how an individual perceives a situation will affect their emotionality, and that individuals with disorders marked by affective distress are experiencing automatic thoughts, distortions in their thinking, dysfunctional beliefs, and/or biases in their perception (Beck, 2008). However, the mechanism by which CBT causes therapeutic improvements remains elusive, but is presumed to function within our information processing systems (Beck, 2008).

Cognitive Information Processing

In classic information processing theory (IPT), cognitive processing of decisions entailed a stepwise progression through hypothesized functional cognitive structures, such as sensory registers, attention, and different aspects of memory, although some structures were ascribed recursive loops, to allow iterative processing of information within a larger, self-regulated behavioral system (Miller, Galanter, & Pribram, 1960). An individual was presumed to perform an initial test of information (Test), perform some type of cognitive processing (Operate), and perform additional tests (Test) that would either lead to a decision (Exit) or additional operations and tests as needed. These Test, Operate, Test, Exit (TOTE) processes were conceptualized as either individual or nested to allow for goal related decision making in the midst of continuous behavior and not simply the reaction to a single stimulus.

Within the context of behavioral output alone, this information processing model was functional, but was not thought to reflect the actual processes within neural systems, prompting the creation of a parallel distributed processing model (PDP; Rumelhart, Hinton, & McClelland, 1986). This model proposed multiple disparate processing units, without specific and linear information storage, able to send excitatory or inhibitory signals to the other units. Thus, cognitive information processing could not be represented as simply a linear process, and different states of activation, learning rules, and output functions for each unit were presumed to summate to the overall behavioral output of the processing (i.e., decision). If the overall cognitive model of mental illness is indeed operating to cause dysfunctional behavioral output, identifying the dysfunctional processes could allow for greater localization of the neurological basis of the disorders.

Within both models, the processing was only presumed to occur, with no direct measurement of the operation or processing steps. Within both systems, the actual behavioral output is viewed as the culmination of the processing steps and that different test steps (IPT) or processing unit connectivity (PDP) would moderate the probabilities of outputs. From the external view, even something as simple as a binary decision making process may appear linear, but involve a distributed, complex process within the brain. The distributed processing model makes the localization of any cognitive dysfunction within mental illness more difficult, as the recruitment of disparate regions in information processing includes the possibility of numerous dysfunctional areas (Beck, 2008). Studies linking cognitive and biological correlates of depression have identified numerous predisposing genetic vulnerabilities affecting monoamine neurotransmitters (Caspi et al., 2003; Wichers et al., 2007). In addition, neurophysiological evidence has been instrumental in linking the neurobiological and cognitive processes active in eliciting depressive symptoms through the processing of negative stimuli (Siegel, Carter, & These, 2002) and the anticipation of negative stimuli (Abler, Erik, Hedwig, & Walter, 2007). The proposed neurobiological basis of these cognitive biases consists of amygdalar hypersensitivity to negative stimuli and biasing both the processing and storage of emotionally charged events (Siegel, Thompson, Carter, Stein Hauser, & These, 2007).

However, this biasing of the amygdala does not occur within a vacuum, but involves the interaction of numerous brain areas, including reduced prefrontal functioning in nearly all depressed patients (Siegel et al., 2007). It has been suggested that prefrontal circuitry involved in the down-regulation of the amygdalar processing of negative stimuli, specifically the left lateral ventral medial prefrontal circuit, is not properly engaged in depressed individuals, while the right prefrontal cortex is overly engaged (Johnston, van Rectum, Uri, Kalyn, & Davidson, 2007). Similarly, the orbitofrontal and dorsolateral medial prefrontal cortices are also implicated in regulating amygdalar activity and reduced frontal-limbic connectivity has been shown to predict individual attenuation of negative affect aroused by negative stimuli (Banks, Eddy, Angstadt, Nathan, & Phan, 2007). In addition, the rostral anterior cingulate cortex has shown abnormal responsivity to performance errors in depressed patients (Pizzagalli, Peccoraldo Davidson, & Cohen, 2006). Thus, exerting top-down cognitive control over both cognitive processing biases and emotional processing are important in understanding the links between cognitive processing and affective mental illnesses, including both depressive and anxiety disorders (Beck, 2008).

Executive Functions

Numerous theoretical models of executive functioning have proposed various cognitive processes regulating behavior, including attention, initiation of behavior, action and outcome monitoring, working memory, planning, problem solving, regulating social behavior, and decision making (Chan, Shum, Toulopoulou, & Chen, 2008). In effect, these functions focus on coordinating actions and responding adaptively to novel situations and are grossly attributed to the functioning of the frontal lobe (Lezak, Howieson, & Loring, 2004). However, a number of structures are consistently identified as important in executive functions focused on planning and complex decision making, including the prefrontal cortex (PFC; medial and dorsolateral), orbitofrontal cortex (OFC), basal ganglia, and anterior cingulate cortex (Brown, Schneider, & Lidsky 1997; Damasio, Grafman, Holyoak, & Boller, 1995; Devinsky, Morrell, & Vogt., 1995; Hampton, Adolphs, Tyszka, & O'Doherty, 2007; Hampton & O'Doherty, 2007; Holroyd et al., 2004; Posner, DiGirolamo, & Parasuraman, 1998). It is yet unclear how these executive functions are related to affect and emotion, but appears to vary by specific function, with some functions appearing to be relatively unemotionally arousing, while others involve more emotional output and regulation of emotion (Bechara, Damasio, Damasio, & Lee, 1999). Those commonly described as logical and unemotional include verbal reasoning, planning, problem-solving, sustaining attention, sequencing, and utilization of feedback (Grafman & Litvan, 1999).

Damasio's somatic marker model emphasizes the frontal lobe in decision making as a component of the control of emotion and social behavior (Damasio, 1995). This model suggests that frontal regulation of emotion includes both cortical and subcortical feedback, and that executive functions pertaining to social behavior regulation, decision making pertaining to emotional and personally relevant information, and reward and punishment processing use more information pertaining to emotionality (Bechara, Damasio, Damasio & Lee, 1999; Damasio, 1995; Grafman & Litvan, 1999). This becomes difficult as processing of information to monitor performance, utilizing feedback, is thought to be unemotional while reward and punishment processing is ascribed emotional significance, suggesting some conflict when rewards and punishments are the feedback needed to adjust behavior. This suggests that cognitive and affective information processing may both influence decision making in these tasks.

Affective Information Processing

Historically, investigations of decision making have excluded emotional processes and focused on purely cognitive aspects of information processing (Cacioppo & Gardner, 1999). Perhaps this has been due to the over ninety different definitions of emotion and large number of theories of emotion differentially focusing on bodily feedback, regulatory versus activation functions, and primacy versus secondary position in information processing (Plutchik, 2001). This affective system is thought to be closely related to organismic behaviors regulating approaching opportunities and avoiding threats, and thus, all other domains of processing involved in these whole body tendencies (Damasio, 1999).

Communicative theory (Oatley & Johnson-Laird, 1995) is one example of a theory that views emotions as an event resulting from cognitive evaluations, which aids in goal related behavior by readying bodily responses, directing attention to the evoking stimuli, and creating cognitive biases for later processing. This suggests that emotions are downstream signals in responses to initial goal-related decisions, which could affect later decisions through other cognitive processes. However, other theories suggests the primacy of emotions, as reactionary tendencies to move the entire body toward or away from stimuli, beginning with an appraisal system that evaluates internal and external stimuli, with the cognitive decision making processes being recruited by the affective system (Damasio, 1999).

However, it is now recognized that cognitive and affective processes are simultaneous, involve numerous identical neurobiological mechanisms, and likely represent a singular process (Davidson, 2000). But, developing unified cognitive and affective models of decision making will require the differentiation of components and understanding the parallel and interactional processes. This would require modification of both the cognitive and statistical models of decision making theory by including affective state information as a component or moderator of the decision making process at each level: context, decision, and evaluation.

When looking solely at the affective components of information processing, three major processes are commonly identified: evaluating the emotional salience of a stimulus, expressing the complex responses to the emotion, and experientially experiencing the emotion and responses (LeDoux, 1987). The evaluative process involves appraisal of the stimulus valence by processing the stimulus itself, contextual information, and any links with previous reinforcement or conditioning (Izard, 1993). The expressive process is also multifaceted involving facial and behavioral expressions, neuroendocrine and neuropeptide release, and changes in activation patterns of parasympathetic and sympathetic balance (LeDoux, 1987). Finally, the experiential experience of the previous processes, interpreted in an individual’s situational context, is not simply a stimulus reactive process, but is an ongoing experience that provides feedback to expressive processes and influences stimulus evaluative and cognitive processes (Gray, 1990). Thus, attempts to investigate decision making without assessing emotional states and responses to stimuli are inherently incomplete (Ashby, Isen, & Turken, 1999), as behavioral output data could represent attempts to regulate goal attainment or emotional experiences.

Neurophysiological Markers of Cognitive Control

Performance monitoring is a critical component of ongoing and future decision making, as it allows analysis of outcomes for its impact on goal attainment, and feedback of this information into the decision making process, be it cognitive or affective information (Carter et al., 1998; Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004). The conflict monitoring theory is one aspect of this feedback system and holds that the anterior cingulate cortex (ACC) analyzes outcomes for conflicts, and when a conflict is detected, it recruits additional cognitive resources to allow more adaptive behavior generation and finding more optimal responses (Botvinick et al., 2001; Kearns, 2006). The hypothesized neurobiological basis of this recruitment is ACC activation of the right ventromedial prefrontal cortex (PFC) and dorsolateral PFC, which are responsible for directing additional attentional resources to aid in controlling cognitive functions (Egner, 2011; Egner & Hirsch, 2005a, 2005b). This increase in directing attention to task-relevant stimuli and information is theorized to occur from dorsolateral PFC recruitment of parietal attentional structures (Egner & Hirsch, 2005a).

Electrophysiological investigations of cognitive control commonly focus on identifying psychophysiological markers of information processing, both through measures of total task processing (power spectra) and brain processing signatures time-locked to events or stimuli (event-related potentials; ERP). Three major ERPs have been linked to this performance monitoring system and the cingulate cortex. The first is the conflict N2 (Botvinick, Carter, Braver, Barch, & Cohen, 2001), which is theorized to represent a marker of conflict detection and imposing cognitive control and is defined as a negative deflection occurring 250-350ms following incongruent or task irrelevant stimuli, spatially localized at medial frontal electrodes (Clayson & Larson, 2012; Nieuwenhuis, Yeung, van den Wildenberg, & Ridderinkhof, 2003; Yeung & Cohen, 2006). The second, the error-related negativity (ERN; Gehring, Goss, Coles, & Meyer, 1993), also represents engagement of cognitive control following known error commission at medial frontal electrodes, defined as a negative deflection occurring 100ms following erroneous motor responses (Coles, Scheffers, & Fournier, 1995; Gehring, Goss, Coles, & Meyer, 1993; Holroyd, Nieuwenhuis, Mars, Coles, & Posner, 2004; Nieuwenhuis, Holroyd, Mol, & Coles, 2004). Third and finally, the feedback negativity (FN; Miltner, Braun, & Coles, 1997) is believed to represent detection of errors, and is defined as a medial frontal negative deflection occurring 200-350ms following presentation of feedback indicating an error in decision making (Gehring & Willoughby, 2002; Holroyd et al., 2004; Miltner, Braun, & Coles, 1997). These components are elicited in a wide variety of tasks involving error commission and feedback conflicting with goal related behaviors (Holroyd et al., 2004).

The Anterior Cingulate Cortex

The ACC is the proposed neural generator of all three components from source localization studies (Bellebaum & Daum, 2008; Dehaene, Posner, & Tucker, 1994; Gehring & Willoughby, 2002; Holroyd, Dien, & Coles, 1998; Miltner et al., 1997; Yu & Zhou, 2009) and functional neuroimaging studies (Alexander & Brown, 2010; Brown & Braver, 2005; Carter et al., 1998; Holroyd et al., 2004; Stevens, Kiehl, Pearlson, & Calhoun, 2009; Ullsperger & von Cramon, 2001, 2003). This suggests that the ACC is involved in the executive functions of decision making, although whether this relates to simple error detection or the more complicated evaluation of goal-related conflicts remains unclear (Wang et al., 2005; Yeung & Cohen, 2006). Some investigations consider the lack of direct findings between ACC activation and neuropsychological measurements of executive functioning a sign that the cingulate ERP components represent a lower level of executive functioning, much less complex than required for actual behavioral adaptations and recruitment of additional cognitive resources (Clayson & Larson, 2012). There is evidence that the ACC is also an important component of the neural basis of subjective emotional experiences. Stimulation of various ACC regions is associated with reports of pleasure, fear, and anxiety, while focal neurological damage to the ACC of various etiologies is associated with disruption of emotional experience (Devinsky, et al., 1995). However, the cingulate cortex seems extraordinarily complex, composed of a variety of functional regions with different cytoarchitectural organizations and associations with a wide variety of behaviors in addition to emotional experience and error monitoring, including motor output, pain responses, emotional vocalizations and social behavior (Devinsky et al., 1995). As ERP measurements represent the regional summation of pyramidal neuron population activity across a wide spectral area (Luck, 2005), numerous sources of information processing may be represented in these waveforms, suggesting the inclusion of a wide variety of cognitive and affective variables in psychophysiological investigations, to aid in complete understanding of waveform significance.

Even with this heterogeneity of ACC functioning, understanding these components is more difficult as the ACC is directly connected to a wide variety of subcortical structures and cortical areas (for a review, see Vogt & Gabriel, 1993; Vogt, Nimchinsky, Vogt, & Hof, 1995). Three motor control areas have been identified in the cingulate and high interconnectivity with the primary and supplementary motor cortices, basal ganglia, and spinal cord suggest direct involvement with executive functions organizing or modifying motor output (Dum & Strick, 2002; Dum, Strick, Vogt, & Gabriel, 1993). Subcortical connectivity also links the ACC with motor output through direct connections with the amygdala and periaqueductal gray, both implicated in affective based behaviors such as behavioral approach, avoidance, and defense (Gray & McNaughton, 2000), and informing theories that the ACC initiates and modifies affective motor outputs and activates stored motor programs engaged from affective stimuli (McNaughton, 1989). Recent fMRI studies have supported ACC motor output theories with amygdalar activation associated with monitoring the motivational significance of events and activating the dorsal ACC, which shows activity consistent with error monitoring functions and motor outputs (Pourtois et al., 2010).

One of the primary input sources for the cingulate cortex originates from the thalamus, suggesting that the cingulate cortex receives some organized stimulus information and may perform direct evaluative processes (Vogt & Gabriel, 1993). The reinforcement learning theory (RL; Holroyd & Coles, 2002) suggests that mesolimbic neurons provide input to the cingulate following prediction errors through phasic suppression of dopaminergic activity, disinhibiting ACC neurons and eliciting the ERP components following errors or outcome feedback that is worse than expected (ERN/FN). These reward related prediction error signals (temporal difference; TD errors) are conceptualized as occurring for either greater than expected (positive errors) or worse than expected (negative errors) and signal the need for adapting planned behaviors (Holroyd & Coles, 2002; Sutto, Barto, Gabriel, & Moore, 1990). This input has been shown to include areas coding magnitude of error, likelihood and valence, suggesting the need to control for these factors when investigating the reward expectation input to the cingulate cortex (Knutson, Taylor, Kaufman, Peterson, & Glover, 2005).

There is also evidence that the interconnectivity with the frontal lobes could provide expectancy information directly to the cingulate and interact with thalamic stimulus processing input (Vogt et al., 1995). Prefrontal areas have shown to directly code reward and outcome expectancy (Glascher, Hampton, & O'Doherty, 2009; Hampton et al., 2007; Knutson & Cooper, 2005; Knutson et al., 2005; Knutson & Wimmer, 2007), and reward sensitivity biases have been source localized to the prefrontal and orbitofrontal cortices (Pizzagalli, Sherwood, Henriques, & Davidson, 2005). This would suggest that the cingulate cortex could independently conduct error and conflict processing by comparing prefrontal outcome expectancies and thalamic sensory input, and not depend solely on reward related input from the mesolimbic dopamine system, particularly during novel tasks that engage more use of executive functioning to plan responses (Baddeley, 1986; Georgopoulos et al., 2000; Luria & Pribram, 1973). Thus, some distributed processing of prediction errors is possible, with the mesolimbic system handing reward related outcome processing with learned reinforcement information and the caudate nucleus and prefrontal areas coding novel prediction errors (Cohen, 2007).

Neuropsychology of Anxiety

One theory implicated in the processing of reward and punishment information is the reinforcement sensitivity theory (RST; Gray & McNaughton, 2000) which outlines a conceptual nervous system to link theorized functional systems with neurobiological systems. This system proposes three functional systems regulating adaptive behaviors: the Fight-Flight-Freeze System (FFFS), the Behavioral Activation System (BAS), and the Behavioral Inhibition System (BIS; Gray & McNaughton, 2000). The FFFS is activated by fear, frustration, or threatening stimuli and regulates escape or defensive freezing behaviors, or elimination behaviors including anger and attack. The BAS is sensitive to conditioned and unconditioned rewarding stimuli and regulates adaptive approach behavior. The BIS is sensitive to any goal conflicts between systems, such as between approach motivation toward possible threats (approach-avoidance), which regulates defensive approach behaviors such as passive avoidance, vigilance, rumination, as well as anxiety (Gray & McNaughton, 2000; Perkins & Corr, 2006; Perkins, Kemp, & Corr, 2007).

The proposed neurophysiological basis of these systems includes a wide variety of neurological systems. The FFFS includes the septo-hippocampal system, amygdala, medial hypothalamus, and central grey (Gray, 1990). The BAS is highly linked with the dopaminergic projections from the ventral tegmental area and substantia nigra to the basal ganglia, the ACC, and the frontal cortices, with close connections between BAS functioning and the dopaminergic portions of the system (Depue, Iacono, Rosenzweig, & Porter, 1989; Depue, Luciana, Arbisi, Collins, & Leon, 1994; Gray, 1990). The BIS has been linked to the serotonergic projections from the raphe nucleus to the septo-hippocampal system (Gray, 1982), amygdala (Kagan, Snidman, & Arcus, 1992), and noradrenergic mediated fibers to the locus coeruleus, with close connections between serotonergic elements and the BIS (Cloninger, 1987; Depue et al., 1989). The BIS also is implicated in cognitive detection of conflict through detection of conflict within fields CA1 and CA3 of the hippocampus and the subiculum, in order to increase negative affective bias and inhibit motor programs when goal-oriented conflicts are detected (Gray & McNaughton, 2000). Many of the proposed functions of the BIS are identical with theories of cognitive control, including increasing attention and vigilance (Corr, Pickering, & Gray, 1997), through BIS outputs to the cerebellum, amygdala, prefrontal cortex, and cingulate cortex, positioning the BIS as possibly providing additional input to the ACC cognitive control ERP components. This is further complicated by the theorized interactional nature of the systems to produce behavioral outcome (Corr, 2002). This interaction suggests functional system separation in some conditions where the activating stimuli are extremely strong and clearly indicate a specific response (Corr, 2001, 2004). In most cases, the behavioral output would represent the relative strength of response between systems and individual differences in system responsivity (Corr, 2004). This differential engagement has been shown based on experimental condition manipulation (Avila & Torrubia, 2004; Gomez, Cooper, McOrmond, & Tatlow, 2004; Kambouropoulos & Staiger, 2004; Knyazev & Wilson, 2004).

Anxiety and anxiety symptoms are a normal human responses to threats and negative stimuli (LeDoux, 1996), aiding in the normal human capacity to exert cognitive and emotional control over the environment and maintain readiness and behavioral flexibility (Ninan, 1999). This normal anxiety responsivity includes blunted pain perception, autonomic activation, and activation of the hormonal stress response through the hypothalamic-pituitary-adrenal (HPA) axis (LeDoux, 1996). As mentioned in the context of depressive disorders, the reciprocal connectivity between the medial prefrontal cortex and the amygdala helps regulate these responses with medial PFC cognitive, top-down regulation of the responses (Ninan, 1999). However, times of increased stress and threat switch control to the amygdala in a bottom-up fashion (Arnsten, 1998). In either case, the central nucleus of the amygdala (CnA) handles output processing along a number of efferent pathways, with each regulating different aspects of the anxiety response (Ninan, 1999). Of note, the CnA activation of ventral tegmental area, locus coeruleus, and dorsolateral tegmental nucleus is implicated in increases in EEG arousal and vigilance responses (Davis, 1992). Thus, FFFS, BIS and ACC conflict processing are purported to aid in proper responses and recruitment of metabolic resources; however, they are also implicated in dysregulated anxiety responses.

The current diagnostic nosology of mental illness (DSM-IV-TR) categorizes anxiety disorders by the core symptom of excessive experience of anxiety, manifested in a variety of different symptom patterns, including worry, panic, irritability, avoidance, restlessness, tension, fear, and somatization (American Psychiatric Association, 2000). Within the neurobiological context of CnA mediated output responses, these pathological responses may be characterized as the loss of cognitive flexibility and cognitive control through behavioral response limitation to the bottom-up, amygdala driven processing and characteristic CnA output activation pattern (Ninan, 1999). Although taxonomically categorized as independent, rates of comorbidity between anxiety and depressive disorders are considerable, at nearly 60% in some clinical samples (Dobson, 1985; Mineka, Watson, & Clark, 1998), and anxiety precedes depression in most cases, suggesting the possibility of an underlying risk factor (Belzer & Schneider, 2004; Hettema, Prescott, & Kendler, 2003). RST proposes that the neurobiological basis of anxiety resides in the interrelationships of these functional systems, through overactive relative BIS functioning in anxiety disorders (Gray & McNaughton, 2000; Johnson, Turner, & Iwata, 2003; Turner, Beidel, & Wolff, 1996) and increased risk for depression in those with high BIS (Kasch, Rottenberg, Arnow, & Gotlib, 2002). If this shared etiological source represents a functional limitation in cognitive control, electrophysiological markers of cognitive control (FN, ERN, and N2) may serve as a marker of cognitive limitations in these disorders.

Cognitive Control in Disorders

Deficits in cognitive control have been described in a wide variety of psychiatric and neurological disorders including traumatic brain injury (Larson, Farrer & Clayson, 2011; Larson, Kaufman, & Perlstein, 2009), schizophrenia (Kerns et al., 2005), depression (Melcher, Falkai, & Gruber, 2008), and anxiety disorders (Etkin, Prater, Hoeft, Menon, & Schatzberg, 2010; Osinsky, Alexander, Gebhardt, & Hennig, 2010). The relationship between executive functioning deficits in these disorders and neurophysiological markers of cognitive control are presumed, but not directly known, although behavioral conflict adaptation has been directly related to measures of executive functioning (attention and verbal fluency) in a normal population (Clayson & Larson, 2012).

It is yet unknown whether neurophysiological markers of feedback processing have any direct relationship to executive functions, either logical or emotional in nature. The overarching goal of this work is to aid in elucidating the relationships between feedback processing and executive functions in varying emotional elicitative tasks. However, the nexus of reward feedback related processing as possibly integrating executive functions governing both emotion regulation and cognitive decision making, suggests the inclusion of variables possibly mediating or moderating these relationships, which may include individual differences in personality, emotion, and affect. However, this implicates numerous different models of personality and emotion, only a selection of which will be included in the current investigation.

Measurement Issues

Executive functions. With the large number of models of executive functioning, there exists conflicting views of how to best assess different elements of executive functions (Chan et al., 2008). One model that has direct implications is the supervisory attentional system (SAS; Norman & Shallice, 1986) and later extensions of that theory. The SAS model suggests that two systems, supervisory attentional and contention scheduling, regulate behavioral output with contention scheduling regulating well learned and automatic behavioral programs, and the supervisory attentional system regulating novel responses. This is consistent with the purported functioning of neurophysiological markers of cognitive control, as they might serve as a signal to engage the supervisory attentional system, as error correction and troubleshooting was theorized to be regulated by the supervisory attentional system (Norman & Shallice, 1986). Suggestions of different assessment strategies commonly include tasks involving conflict processing and inhibition, requiring mental switching and flexibility, and those requiring sustaining attention (Stuss, Shallice, Alexander, & Picton, 1995), however, a multitude of other models include various assessments of working memory, processing speed, planning, and implicate a hierarchical organization based on task demands (Banich, 2009). This suggests the need for a multi-factorial approach to assessing attention and executive functions (Lezak, 2004), and the inclusion of tasks assessing processing speed, working memory, sustained attention, planning, set shifting, conflict, and flexibility in responding.

However, all of these facets of executive functioning are unlikely to be closely related to neurophysiological markers of cognitive control. One model suggesting a link between neuroanatomical functioning and task specific behavioral requirements is the cascade of control model (Banich, 2009). Herein, the planning activities of the dorsolateral PFC selects an attentional set to accomplish a goal, with the subsequent engagement of processing biases and selectively attending to task-relevant information also being mediated by the dorsolateral PFC. The actual response selection is suggested to occur in the posterior dorsal ACC, with the anterior dorsal ACC evaluating responses (Banich, 2009). This suggests that tasks engaging ACC error monitoring (i.e. Stroop type tasks) would be more closely related to ACC activation than those involved in planning. Similarly, as actually shifting attentional sets, and thus mental flexibility, in response to perceived errors would also be the result of ACC activation, these tasks should also be related to ACC error responses. Tasks involving more engagement of processing speed, working memory, and sustaining attention over other executive functions should, theoretically, not be as closely related. This is again a cognitively focused model, and does not fully integrate engagement of emotional processing as another possible attentional set that could engage the more emotionality focused areas of the ACC.

Emotion/affect. Investigating the link between emotional states and cognitive control remains difficult, as a number of phenomenologically different emotional experiences and emotional states may be described. To help clarify these relationships, a number of dimensional models of emotion have been described. Russell described a circumplex model of affect in which emotions may be described by their relative positions on arousal (arousal-sleepiness) and valence (pleasure-displeasure) dimensions within a two dimension Cartesian orthogonal space (Russell, 1977; 1980). Plutchik developed an alternative circumplex model within a similar two-dimensional space that includes more basic emotions closer to the origin and more complex emotions represented as more distant (Plutchik, 2001). A more recent dimensional model proposes a direct relationship between the phenomenological experiences of eight basic emotions and relative combinations of the monoamine neurotransmitters (Lövheim, 2012). This model posits a three dimensional cubic space in which norepinephrine, dopamine, and serotonin form the axes with the basic emotions labeled at the corners of the cube, but remains untested.

Alternative independent dimensional models have also been proposed in which positive affect (PA) and negative affect (NA), roughly equating with the pleasure-displeasure dimension in the circumplex models, are conceptualized as two separate dimensions instead of bipolar opposites of a single dimension, although it is acknowledged that these dimensions may be affected by other constructs such as overall arousal (Watson, Clark, & Tellegen, 1988). While this independence has been hotly debated from the differing perspectives on subjective self-report measures and measurement issues (Green, Goldman, & Salovey, 1993; Russell & Carroll, 1999), neurobiological evidence supports different neural circuitry generating positive and negative affect (Cacioppo & Berntson, 1994).

Affective may directly affect information processing and overall cognitive approach, with negative affect eliciting an externally focused, bottom-up thinking approach, and positive affect eliciting an internally driven, top-down approach (Bless & Fiedler, 2006). Positive affect has been linked to increased cognitive flexibility and reactivity, increased distractibility, and impaired maintenance capability, presumably through prefrontal dopamine release (Ashby, Isen, & Turken, 1999). Thus, positive affect seems to weaken cognitive control (Ashby, Valentin, & Turken, 2002; Dreisbach, 2005). Interestingly, negative affect seems to affect cognitive control via different mechanisms with fear related negative affect inhibiting cognitive control systems, while sadness related negative affect states increase cognitive control mechanism (Melcher et al., 2008).

An additional model directly implicates the frontal lobe in emotion processing through individual differences in relative cortical activity in the frontal lobes causing differences in responsivity to affective stimuli (Coan & Allen, 2004; Davidson, 1993), which are in turn related to disparities in general behavioral approach and withdraw (Coan & Allen, 2004). Specifically, general resting disparity between the left and right frontal lobes, generally inferred from measured alpha band activity, link approach behaviors and responsivity to positive affective stimuli to greater activation of the left frontal lobe and greater withdraw behaviors and responsivity to negative affective stimuli to greater activation of the right frontal lobe (Coan & Allen, 2004; Davidson, Jackson, & Kalyn, 2000; Harmon-Jones, 2004; Tomarken, Davidson, Wheeler, & Doss, 1992; Wheeler, Davidson, & Tomarken, 1993). In seemingly paradoxical findings, studies have shown that hostility is associated with increased relative left hemisphere activity associated during affective learning tasks (Everhart, Demaree, & Harrison, 2008), and similar findings for anger (Carver & Harmon-Jones, 2009), perhaps due to differences in attentional focus (Gable & Harmon-Jones, 2010) or the characterological nature of anger and hostility being associated with approach behaviors and not the withdraw commonly attributed to other negative affective states (Carver & Harmon-Jones, 2009). If integrated with the cascade of control model of executive functioning, this would suggest that asymmetric activation could represent individual differences in the engagement of dorsolateral PFC affective attentional sets and affective response biases. This could also suggest hemispheric specialization in approach versus withdraw planning, resulting in different activation patterns associated with affective motivational states.

Statistical Decision Theories

Statistical decision theories seek to identify the mathematical representations of decisions, and usually do for simple sensory-motor tasks to simplify the number of iterative steps required between stimulus and output (Kersten, Mamassian, & Yuille, 2004). When viewed as a mathematical, probabilistic process, statistical decision theories seek to combine contextual cues and pre-existing ideas of probabilities (Carpenter & Williams, 1995), the active decision making process (Clark, 1997), and any feedback elements into a single model (Carter et al., 1998). Signal detection theory (*SD*T) was originally designed to infer categorical choices from information characterized by a high signal to noise ratio (Green & Swets, 1966), and has been applied to physiological processes and decision making (Parker & Newsome, 1997). In this model, an individual collects a single observation of evidence (e) caused by a presented stimulus or physiological state (usually either present, h_1, or absent, h_2). The *SD*T model seeks to identify the interaction of different elements through relating some decision to *e*, typically through the ratio of likelihoods of the decision during the presence or absence of the stimulus or state:

$$l_{12}(e) \equiv P(e|h_1) \,/\, P(e|h_2).$$

Sequential analysis (SA) adds to this model by looking at the decision as an ongoing process of accumulating multiple pieces of evidence over time ($e_1, e_2 \ldots en$), and the adjustment of the decision, or continuation of previous decision, at each step in the evidence collection process. Within this evolving model, the decision is usually represented as the logarithm of the likelihood ratios for each condition, as the weight of evidence at that time: $\sum_{i=1}^{n} \log(\frac{P(e1,e2,\ldots,ei|h1)}{P(e1,e2,\ldots,ei|h2)}$. This decision analysis framework has been applied to localizing elements of decision making in neurobiologically based investigations, with the conceptualization that subjective value is coded in multiple locations including the orbitofrontal, anterior cingulate, and prefrontal cortices, as well as the basal ganglia, although each area appears to code value based on different parameters, such as choices, consequences, and reward history (Lo & Wang, 2006; Gold & Shadlen, 2007). It is interesting to note that one area, the orbitofrontal cortex, appears to represent value independently of actions, choices, or current external evidence, suggesting that another factor, such as internal, emotional salience of the decisional variable may be influencing its value and affective responding (Padoa-Schioppa & Assad, 2006).

Electrophysiological Markers of Affective Responses

With the activation of both ACC mediated emotional responses and amygdala (CnA) output activity, various psychophysiological measures are theorized to reflect affective responses to stimuli. Both ACC and amygdala activity are strongly associated with metabolic regulatory processes including blood pressure and cardiac regulation (Fredrikson et al., 1998; Critchley et al., 2003). Tonic measures of these responses summate autonomic responsivity over time, including electrodermal responses, averaged heart rate, and cortisol responses, and do not have enough temporal sensitivity to investigate autonomic responsivity on a trial-by-trial basis (Lole, Gonsalvez, Blaszczynski, & Clarke, 2012). One commonly used, temporally sensitive measure of autonomic nervous system activation is heart rate variability (HRV), assessed through electrocardiographic (ECG) measurements of R-wave time intervals between beats on an individual's response to a task that requires cognitive or affective processing or during a resting or meditational state (Sandercock, Bromley, & Brodie, 2005). Two major indices are normally derived based on oscillatory patterns, with low-frequency (LF; 0.05-0.15 Hz) oscillations thought to primarily reflect sympathetic nervous system activity (Pagani et al., 1986; Montano, Porta, & Malliani, 2001), while high-frequency (HF; 0.15-0.50 Hz) oscillations thought to reflect vagally mediated parasympathetic activity (Montano et al., 2001). Thus, HRV indices are thought to represent differential sources of autonomic nervous system homeostatic regulation mechanisms to respond and adapt to situations with physiological or psychological demands (Hjortskov et al., 2004; Segerstrom & Nes, 2007). Specifically, increased reactivity is thought to reflect healthy autonomic responsivity and behavioral flexibility (Porges, 2011; Thayer, Hansen, Saus-Rose, & Johnsen, 2009).

Reduced HRV is thus a marker of autonomic rigidity and has been shown to be reduced for both depressive and anxiety disorders as an additional biomarker of emotional dysregulation (Thayer & Lane, 2000). This has important implications for health, as reduced HRV oscillations have been shown to predict cardiovascular disease and cardiac mortality in patients with anxiety disorders and depressive disorders with underlying anxiety, in particular generalized anxiety (Kemp, Quintana, Felmingham, Matthews, & Jelinek, 2012). Thus, links between the electroencephalographic markers of cognitive control deficits in these disorders may represent a cognitive precursor to the behavioral and autonomic inflexibility associated with these disorders, and related to the proposed underlying shared neurochemical risk factors, and whether these are engaged in different contexts.

System Amalgamation

From a global perspective, the consistent link between the dopaminergic activity with the Plasticity (β) meta-factor, prefrontal functioning, BAS, mesolimbic projections to the cingulate, and positive affectivity suggests a proposed link between these various cognitive and affective elements. Indeed, many of these factors have been related, such as BAS functioning and increased left frontal baseline activity (Coan & Allen, 2003; De Pascalis, Varriale, & D'Antuono, 2010; Harmon-Jones & Allen, 1997; Hewig, Hagemann, Seifert, Naumann, & Bartussek, 2006; S. K. Sutton & Davidson, 1997), and the BIS system, right prefrontal activity, and ERP responses in conflict processing (Wacker, Chavanon, Leue, & Stemmler, 2010). These have also been shown to be linked to ACC mediated cognitive control markers (De Pascalis et al., 2010; Chavanon, Stemmler, & Wacker, 2008; Pizzagalli et al., 2005). Many of these elements overlap considerably in their functional significance and behavioral output (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997).

The other hypothesized elements including more specific personality models, electrophysiological asymmetry models, affect and emotion models, and psychopathology could represent different expressions of individual variation in these more basic elements.

When reflected in the processing of cognitive control markers, these various elements might only be engaged under specific circumstances, which could account for variations in findings between the FN, ERN, and conflict N2 and these elements. Perhaps tasks involving a high level of cognitive load and little affective significance differentially engage measures related to executive functioning, while tasks involving affective significance engage systems for regulating emotion, including the frontal asymmetry, emotion, and personality traits, and autonomic responsivity. Similarly, those with deregulated anxiety responses might show restricted markers of cognitive control and autonomic regulation, but much more strongly in gambling tasks. Thus, the FN could be activated in a similar manner to different types of conflict (goal or affective) when regulated in either a top-down or bottom-up fashion, and subsequently engage different types of behavioral adaptation responses (goal attainment or affect response regulation).

This work was undertaken to investigate these possible relationships in support of the National Institute of Mental Health strategic objectives. Specifically, this work is designed to support strategic objective 1.3, which prompts researchers to identify and integrate biological makers (biomarkers) and behavioral indicators associated with mental disorders (National Institute of Mental Health, 2008). To address this objective, four major hypotheses were investigated throughout this work. The first hypothesis proposed that factor analyzed personality measures including five-factor scores, trait anxiety, and reinforcement sensitivity measures would yield two overall latent factors roughly equivalent to Stability and Plasticity. Secondly, it was proposed that FN responses between pattern response learning and a cued probability based task would significantly differ and significantly relate to measures of heart rate variability, with increased LF/HF HRV oscillations, suggestive of higher sympathetic nervous system activity, evidenced for gambling tasks. Third, it was hypothesized that neuropsychological measures of attention/working memory, inhibition, and set shifting would be related to neurophysiological measures of processing feedback indicative of goal conflicts in tasks eliciting a cognitive attentional set (pattern task), but not in tasks suggestive of an emotion regulation attentional set (gambling task), while the factor analyzed personality and affective measures would be significantly related to neurophysiological measures of feedback processing in tasks eliciting an emotion regulation attentional set (i.e. gambling), but not tasks eliciting a cognitive attentional set (i.e. pattern learning tasks). Fourth and finally, it was hypothesized that clinical anxiety would increase behavioral level responses, with participants focusing on reward frequency over maximizing rewards, as reflected in behavioral preferences for tasks eliciting a cognitive attentional set over one eliciting an emotional attentional set.

Chapter 2: Factor Analysis of Personality Measures

Literature Review

Personality is commonly conceptualized as a global pattern of characteristics that influences behavior, cognitions and emotions in a variety of situations (APA, 2000). As such, these personality characteristics may be an additional factor impacting decision making related to cognitive control. A large number of personality theories and models have been described; however, many of these remain theoretical constructs not grounded in neurobiological theory (McAdams, 2009). One of the first theories to have such a basis was created by Hans Eysenck, who described three large "super factors" of personality named Extraversion, Neuroticism, and Psychoticism, which were described as independent and orthogonally laid out within a graphical space, with biological theory grounding each individual factor (Eysenck & Eysenck, 1985). Eysenck (1967) linked both Extraversion and Neuroticism with the functioning of the Ascending Reticular Activating System through different circuits: Extraversion through the reticulo-cortical circuit and Neuroticism the reticulo-limbic. Psychoticism was never clearly developed with regards to a neurobiological basis, but was suggested to be positively associated with dopamine (Eysenck, 1997). Extraversion in Eysenck's model was a response to lower overall internal cortical arousal causing sensation seeking behaviors to achieve increased arousal, the ideal level of which was theorized to be an individual difference (Eysenck, 1967). Neuroticism was suggested as greater emotional lability due to easier limbic arousal from emotion-inducing stimuli, which again represented a measureable individual difference (Eysenck, 1967).

Jeffrey Gray, Eysenck's student, developed his own personality model (Reinforcement Sensitivity Theory; RST) which was discussed previously as a proposed basis of anxiety. In review, this theory also described three factors of personality that govern approach and withdraw behaviors: the Behavioral Activation System (BAS), the Behavioral Inhibition System (BIS), and the Flight-Fright-Freeze System (FFFS). However, this theory also hold implications for moderating the cognitive and affective information processing linked to cognitive control efforts due to its neurobiological basis. RST describes the functioning of the BAS, BIS, and FFFS as varying by individual, with the combined output of these systems resulting in personality traits named Anxiety and Impulsivity (Gray, 1972, 1981, 1982) as 45^{o} rotations of Eysenck's Neuroticism and Extraversion orthogonal dimensions, later reconceptualized as 30^{o} rotations (Pickering, Corr, & Gray, 1999). However, the direct relationship between these functional systems and cognitive control are downplayed in the original theory, causing difficulties in directly linking subsystem functioning and cognitive processing elements (Matthews & Corr, 2008). In addition, the RST is inherently organized as a bottom-up processing scheme that may only be engaged in more novel situations that are not driven by established behavioral patterns.

Trait theories are largely statistical abstractions grouping hierarchically organized traits together into broader traits based on some presumed underlying cause (Haig, 2005). The Five-Factor Model of personality suggests that all trait descriptors may be organized within five dimensions: Openness/Intellect, Conscientiousness, Agreeableness, Neuroticism, and Extraversion (Costa & McRae, 1992; Digman, 1990; Hofstee, de Raad, Goldberg, 1992). This model holds implications of integrating earlier taxonomic theories in that Extraversion and Neuroticism are essentially the same as Eysenck's conceptualizations (Goldberg & Rosolack, 1994), such that BAS has been suggested as best assessed through Extraversion measures (Pickering, 2004; Smillie, Pickering, & Jackson, 2006), and BIS assessed with measures related to Neuroticism (Gray & McNaughton, 2000), suggesting that each theory is linked by underlying constructs (Elliot & Thrash, 2002; Zelenski & Larsen, 1999). The Five-Factor Model has been consistently shown to share an even higher-order factor structure due to factor intercorrelations (DeYoung, 2006; DeYoung, Peterson, & Higgins, 2002; Digman, 1997; Jang et al., 2006). Two higher-order factors have been described, the first termed Stability (or α), consisting of Agreeableness, Conscientiousness, and reversed Neuroticism, and the second termed Plasticity (or β), consisting of Extraversion and Openness/Intellect, with both shown to be linked with underlying genetic variation (Jang et al., 2006). It is theorized that these meta-traits are linked to neurochemical functioning with Stability related to serotonin and Plasticity to dopamine (DeYoung, 2006; DeYoung et al., 2002; Yamagata et al., 2006). As these neurotransmitters are related to numerous different neurological functions and systems, they may represent underlying individual differences affecting many diverse trait and surface level behaviors.

Looking more specifically at the dopaminergic aspect of this taxonomy, due to its implicated role in the expression of the cognitive control ERP measures, provides additional evidence that it may underlie individual differences in FN responses to feedback. Dopaminergic activity is related to Extraversion (Depue & Collins, 1999; Wacker, Chavanon, & Stemmler, 2006) and behavioral approach, positive affect, and cognitive flexibility (Ashby, Isen, & Turken, 1999; Braver & Barch, 2002). In addition, catechol-0-methyltransferease (COMT) gene variation, which regulates synaptic dopamine degradation differentially by allele expression, has been related to increased FN response in homozygous Met allele individuals (Foti & Hajcak, 2012), and Openness/Intellect (Harris et al., 2005). Thus, dopaminergic functioning may represent an underlying factor through which both affect and personality measures influence cognitive control measures.

Similarly, the Stability meta-trait may integrate negative affect and personality effects on cognitive processing. Variations in the 5-HTTLR (serotonin transporter gene) are associated with both low Neuroticism and Agreeableness (Jang et al., 2001), and differences in processing positive emotional stimuli (Demaree et al., 2009), while monoamine oxidase-A gene variation is associated with serotonin levels and Agreeableness and Conscientiousness (Rosenberg et al., 2006). In addition, low Neuroticism and high Conscientiousness are associated with increased serotonin responsivity (Manuck et al., 1998). Given the research on how low levels of serotonin are linked with negative affective states, depression, and anxiety, serotoninergic activity could underlie negative affect, behavioral inhibition, and portions of the trait personality structure (DeYoung & Gray, 2009).

Investigation of these interrelationships may represent a hierarchical organization with the most basic level representing individual differences in dopaminergic and serotoninergic gene expression and global brain differences in neurochemical functioning, which is expressed in the meta-trait elements of personality (Stability and Plasticity). While there is evidence to support the inclusion of the loadings from the five factor model, many of the included measures have never been simultaneously factor analyzed, resulting in the need for these initial exploratory analyses.

- *Hypothesis 1 – Principal Factor Analysis of BIS/BAS, AMS, STAI, PANAS, and Mini-IPIP measures would yield two latent factors equivalent to Stability and Plasticity. Specifically, Stability was hypothesized to be composed of reversed behavioral inhibition, reversed trait anxiety, reversed negative affectivity, and measures of Agreeableness, Conscientiousness, and reversed Neuroticism, while Plasticity was hypothesized to be composed of behavioral activation, positive affectivity, appetitive motivation, and measures of Extraversion, and Openness/Intellect (DeYoung, 2006; DeYoung, Peterson, & Higgins, 2002; Digman, 1997; Jang et al., 2006).*

Study Overview

This initial study focused on exploratory factor analyses of personality data in order to both explore interrelationships between inventories and to identify which measures to include in more lengthy neuropsychological and electroencephalographic procedures designed for follow-up studies. It was hoped that these procedures would both reduce participant burden for these later studies and allow for data reduction for multivariate statistical analyses in these later studies. The study was approved by the University and Medical Center Institutional Review Board (UMCIRB) prior to participant recruitment (Appendix A).

Participants

Sample size estimates were based on the inclusion of approximately 14 measures into the inter-correlation matrix for a principle factor analysis, and using the suggested 20:1 subject to measure ratio for sufficient sample size, at least 280 subjects were needed. Total sample size was set at 320 to allow additional cases should cases need to be deleted as indicated during data screening. These three-hundred-and-twenty healthy, adult undergraduate participants with ages ranged from 18 to 26 years (M = 19.6, SD = 1.8) were recruited from the Psychology Department participant pool and were provided class credit for participation in online survey completion (167 women, 153 men). All participants were pre-screened for having no history of neurological or psychological disorders. All participants provided electronic informed consent prior to the start of survey completion. Completion times ranged from 5 to 30 minutes and were negatively skewed (-2.32). Participants completing the surveys in less than 10 minutes (n = 10) were removed from later analyses as outliers with questionable data reliability. Cases with missing values (n = 8) were analyzed by computing a dummy variable coding the presence or absence of each variable missing cases. These dummy variables were not significantly correlated with any other variables, so cases were considered missing completely at random and deleted. The remaining 302 cases (155 women, 147 men) were retained for factor analytic procedures. Response times for this final participant pool ranged from 11 to 30 minutes (M = 23.91, SD = 4.67), although these were still slightly negatively skewed (g_2 = -1.16) and squared duration times were computed for later analyses.

Psychological Inventories

All participants completed a number of self-report inventories. Specific psychometric properties of these measures are presented in Appendix B. Measures included the trait anxiety measure from the State-Trait Anxiety Inventory – Form Y (STAI; Spielberger, 1983) and the Positive and Negative Affective Schedule (PANAS; Watson, Clark, & Tellegen, 1988), presented as a trait measure to yield two separate estimates of trait positive affect (with high arousal) and trait negative affect from subjective ratings of twenty selected affect-related adjectives. Participants also completed Carver and White’s (1994) BIS and BAS scales. This measure was created under the original RST theory, and yields a single measure of BIS and a tripartitioned BAS, in which different aspects related to BAS, namely reward sensitivity, impulsivity, and behavioral approach, result in three scales purporting to measure drive (D), reward responsiveness (RR), and fun seeking (FS). In addition, participants completed the Appetitive Motivation Scale (AMS; Jackson & Smillie, 2004), as an additional measure of BAS functioning developed in the wake of the RST revision, yielding a unitary measure more closely related to reward responsiveness than BAS drive or fun seeking from Carver and White’s scales (Cooper, Smillie, & Jackson, 2008). The measure selected to estimate the Five-Factor Model of Personality was the Mini-IPIP (International Personality Item Pool; Donnellan, Osald, Baird, & Lucas, 2006), a 20-item measure with adequate psychometric properties and overall five-factor structure consisting of Extraversion, Agreeableness, Conscientiousness, Openness/Intellect, and Neuroticism (Cooper, Smillie, & Corr, 2010). The Mini-IPIP was selected due to the rapidity that it may be completed when compared to the more lengthy inventories of the Five-Factor Model, although exploratory factor analyses were planned to confirm the Mini-IPIP's adequacy for estimating these factors in our population. Item analyses were not completed on the other measures, as they have been validated for use in our laboratory in previous studies.

Results

Mini-IPIP item analysis. The 20 items from the Mini-IPIP were factor analyzed to identify if this measure was operating with a five-factor structure in the current population. The Kaiser-Meyer-Olkin measure of sampling adequacy (MSA) was .729, above the recommended value of .6 and Bartlett's test of sphericity was significant, χ^2 (190) = 1667.53, $p < .001$. Inspecting the MSA for each item from the diagonals of the anti-image correlation matrix revealed that the MSA for every item was above .652, with the exception of item 19 ("I seldom feel blue"), which was .517, slightly above the .5 level described as acceptable for inclusion in a factor analysis. In order to preserve the basic structure of the measure, all items were retained.

Principal factor analysis was used to extract the common variance and not include unique variance among the variables. Review of initial Eigenvalues identified six factors with initial Eigenvalues greater than 1, explaining 63% of the variance among the items. Review of the scree plot suggested a five factor solution. This was supported by a parallel analysis, indicating a five factor solution, although both original and revised MAP tests suggested a four factor solution. In keeping with the original makeup of the Five-Factor Model, five factors were retained explaining 57% of the variance among the items, and were rotated using a varimax procedure. Loadings from the final factor solution are shown in Table 1, with items loading as expected from the scoring procedures of the item, with each factor retaining its four items from the original measure, with expected correlations based on additive or reversed scoring procedures. This factor structure is presented graphically in Figure 1. Of note, item 19 did not load well onto any factor, although the highest loading of -.190 was on Neuroticism as expected.

Table 1

Factor loadings based on a principal factor analysis with varimax rotation for the Mini-IPIP items in an undergraduate sample (n = 302)

Items	E	A	I	N	C
16 (Keep in the background)	*.788*	-.030	.151	.062	.003
11 (Talk to a lot of different people at parties)	-*.736*	.160	-.053	-.096	.053
1 (Am the life of the party)	-*.683*	.200	.053	.059	.090
6 (Don't talk a lot)	*.644*	-.123	.121	-.023	.058
2 (Sympathize with others' feelings)	-.107	*.785*	-.145	.098	-.084
12 (Feel others' emotions)	-.063	*.602*	-.116	.157	-.165
17 (Am not interested in others)	.234	-*.587*	.167	.242	.159
7 (Am not interested in other people's problems)	.129	-*.554*	.043	.112	.023
20 (Do not have a good imagination)	.037	-.086	*.746*	.019	.062
5 (Have a vivid imagination)	-.025	.219	-*.690*	.104	.018
15 (Have difficulty understanding abstract ideas)	.056	-.020	*.596*	.347	.021
10 (Am not interested in abstract ideas)	.090	-.062	*.510*	.134	.012
4 (Have frequent mood swings)	.045	.099	.109	*.722*	.117
14 (Get upset easily)	-.030	.004	.132	*.656*	.020
9 (Am relaxed most of the time)	-.169	.173	-.052	-*.457*	-.100
19 (Seldom feel blue)	.001	-.072	.064	-*.190*	-.006
18 (Make a mess of things)	.012	-.033	.053	.188	*.686*
8 (Often forget to put things back in their proper place)	-.061	.086	.025	.101	*.523*
13 (Like order)	.032	.229	.034	.026	-*.518*
3 (Get chores done right away)	-.030	.185	-.020	.014	-*.442*

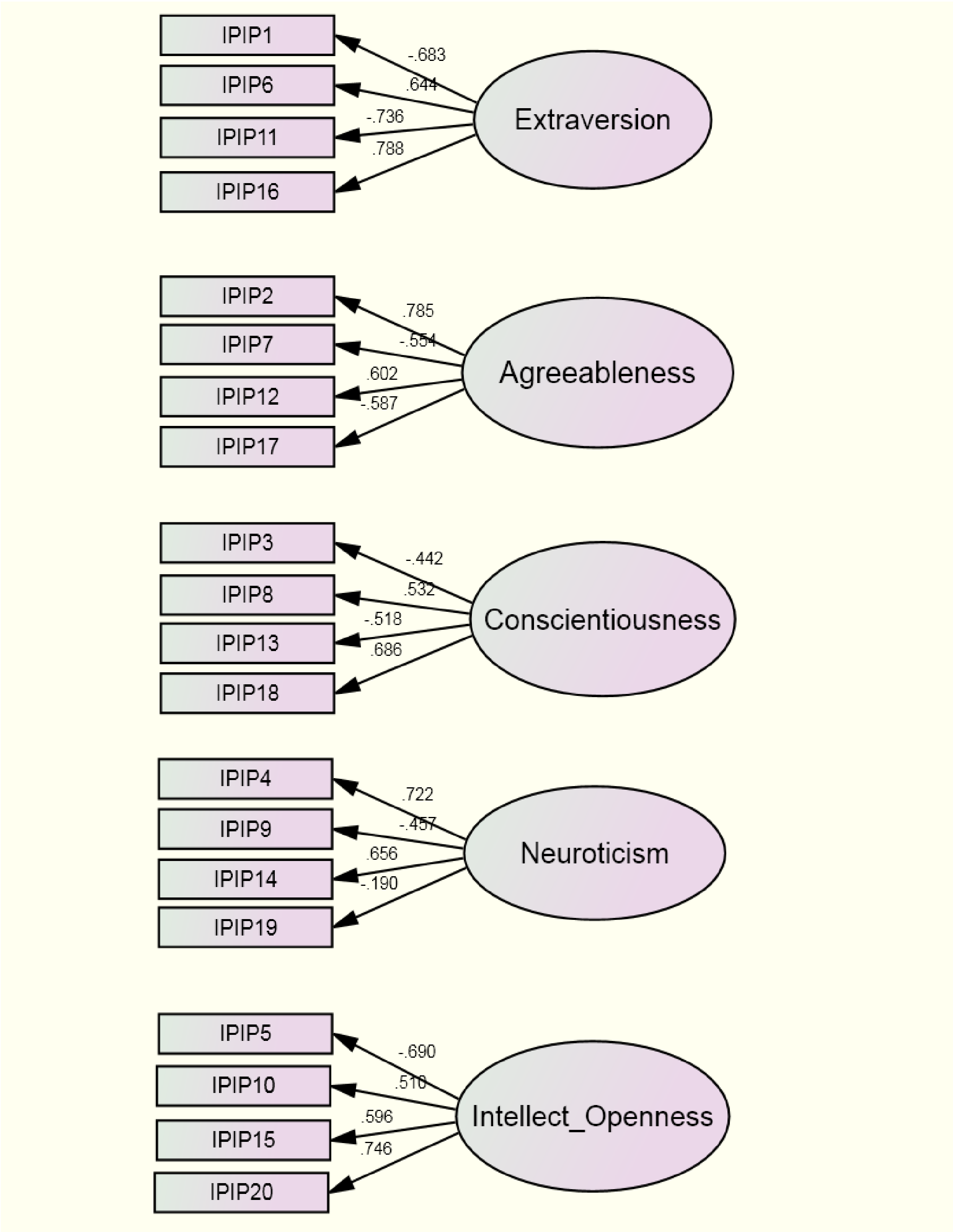

Figure 1 – Mini-IPIP Factor Structure

Correlation analysis. Measures were correlated with total squared response duration (Table 2) in order to explore any relationships between personality and appetitive motivation measures to suggest possible influences on approach to the testing. AMS scores were significantly negatively correlated with response duration, $r = -.145$, $p = .012$, as were BAS reward responsiveness scores, $r = -.161$, $p = .005$, BAS fun seeking scores, $r = -.251$, $p < .001$, positive affect, $r = -.144$, $p = .012$, and agreeableness, $r = -.178$, $p = .002$. Squared response duration was also positively correlated with trait anxiety, $r = .163$, $p = .004$, negative affect, $r = .227$, $p < .001$, and neuroticism, $r = .223$, $p < .001$. This suggests that those with higher levels of anxiety, negative affect, and neuroticism may have taken a more cautious or reflective approach to the test items, while those with higher levels of appetitive motivation measures (positive affect and agreeableness) responded more rapidly, suggesting they may have taken a less cautious approach.

Table 2

Pearson Product Moment Correlations between personality and appetitive motivation measures and squared response duration

Scale	Duration^2	Scale	Duration^2
PA	-.144*	NA	.227***
AMS	-.145*	BIS	.075
BAS-RR	-.161**	STAI-T	.163**
BAS-D	-.015	C	.031
BAS-FS	-.251***	N	.223***
E	-.053	I	-.078
A	-.178**		

Note. * = $p < .05$, ** = $p < .01$, *** = $p < .001$. $N = 302$ for all analyses.

AMS = Appetitive Motivation Scale; BAS-RR = BAS Reward Responsiveness; BAS-D = BAS Drive; BAS-FS = BAS Fun Seeking; BIS = Behavioral Inhibition Scale; STAI_T = Trait Anxiety; PA = PANAS Positive Affect; NA = PANAS Negative Affect; E = Extraversion; A = Agreeableness; C = Conscientiousness; N = Neuroticism; I = Intellect/Openness.

Scale factor analysis. The scores from the BIS/BAS, AMS, STAI-Trait, PANAS, and Mini-IPIP scale scores were entered into a principal factor analysis to identify factors for data reduction in follow up research. Initial analysis indicated that scores were adequate for the analysis, as, the Kaiser-Meyer-Olkin measure of sampling adequacy (MSA) was .766, above the recommended value of .6 and Bartlett's test of sphericity was significant, χ^2 (78) = 1162.17, $p < .001$. Inspecting the MSA for each scale from the diagonals of the anti-image correlation matrix revealed that the MSA for every scale was above .715, with the exception of BIS (.657), although all scales were above the .5 level suggested for retention in the analysis.

Principal factor analysis was used to extract the common variance among the variables. Review of initial Eigenvalues identified three factors with initial Eigenvalues greater than 1.4, the first explaining 27% of the variance, the second explaining 17% and the third explaining 11%, and 10 components with initial Eigenvalue lower than 1. Review of the scree plot suggested a three factor solution. This was supported by a parallel analysis, indicating a three factor solution, although both original and revised MAP tests suggested a two factor solution. Three factors were retained explaining 56% of the variance among the items, and were rotated using a varimax procedure. Loadings from the final factor solution are shown in Table 3. A three dimensional loading plot is shown in Figure 2.

The first factor consisted of trait anxiety (STAI-T), neuroticism (N), negative affect (PANAS-NA), and behavioral inhibition (BIS). The second factor consisted of the fun seeking portion of behavioral activation (BAS-FS), appetitive motivation (AMS), the drive portion of behavioral activation (BAS-D), extraversion (E), and Intellect/Openness (I). The third factor consisted of agreeableness (A), the reward responsiveness portion of behavioral activation (BAS-RR), conscientiousness (C), and positive affect (PANAS-PA).

Table 3

Principal factor analysis with varimax rotation factor loadings for personality and appetitive motivation measures in an undergraduate sample (*N = 302)*

Measure	Suppression	Seeking	Maintenance
STAI-T	*.799*	-.171	-.280
NA	*.734*	.005	-.181
N	*.710*	-.047	-.036
BIS	*.664*	-.091	.445
BAS-FS	-.094	*.703*	-.042
AMS	-.101	*.698*	.028
BAS-D	.062	*.556*	.175
E	-.130	*.477*	.144
I	.030	*.319*	.218
BAS-RR	.050	.400	*.558*
A	-.054	.246	*.511*
PA	-.347	.133	*.437*
C	-.216	-.065	*.397*

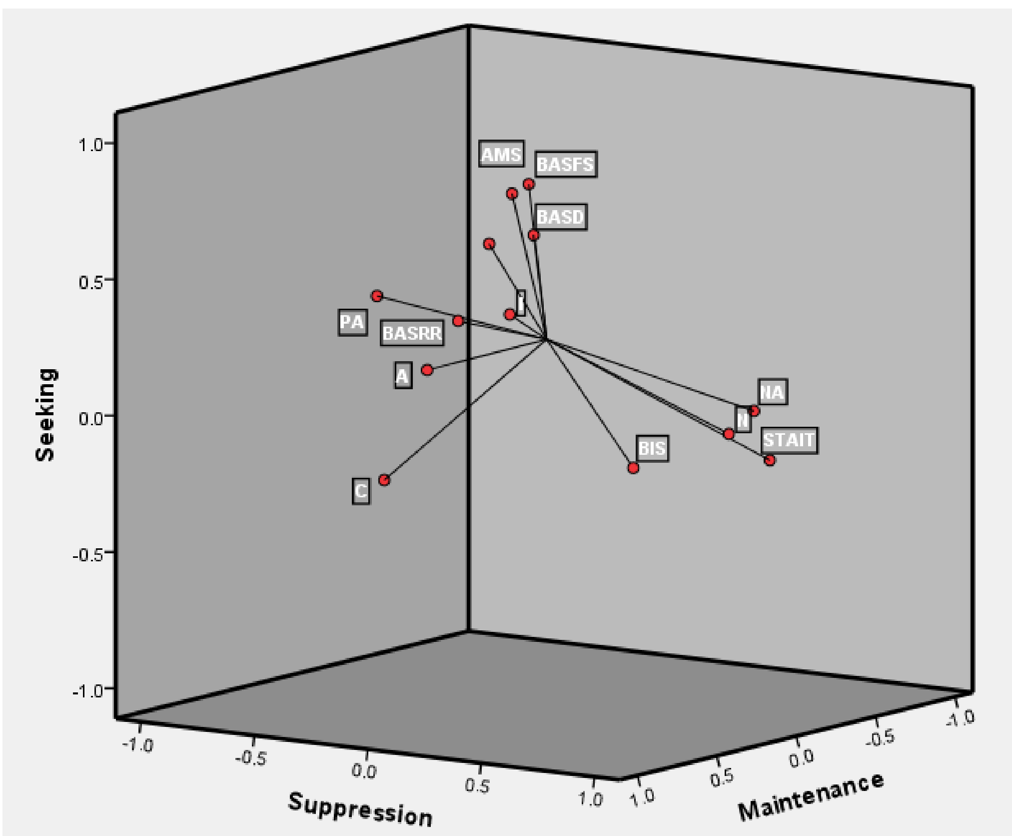

Figure 2 – Factor Loading Plot

Of note, the intellect/openness to experience factor from the Mini-IPIP did not clearly load on a single factor, as it loaded fairly well on both factor 2 (.376) and on factor 3 (.316). Also, positive affect loaded fairly well on all the factors, with the highest loadings on factor 3. The BIS and BAS-RR variables also showed fairly high cross loadings in the current sample, suggesting that these may be closely related to many of the other measures loading onto the second and third factors.

Discussion

Findings suggest that the Mini-IPIP operated as expected on the undergraduate sample utilized in the study. It yielded a five factor structure that captured 57% of the variance among the items. Although, findings suggest that item 19 did not load onto the factor structure as strongly as the other items. This item ("I seldom feel blue") could have been a source of confusion for the participants, as the text of the item uses idiomatic language (blue = sadness) that may not have been clear to many of the participants. It was decided that the text of this item would be updated for use in the follow up studies to increase clarity, being changed to "I seldom feel sad."

The three factor solution to the personality and appetitive motivation measures did not support our hypothesized two factor solution related to Stability and Plasticity. The first factor was composed of measures of anxiety, negative affect, neuroticism, and behavioral inhibition. As these are conceptualized as influences motivating an organism to reduce its' behaviors (avoidance, inhibition), this latent factor was termed Suppression. The second factor was composed of fun seeking, appetitive motivation, drive, extraversion, and to a lesser extent openness to experience/intellect. These measures are suggestive of motivational influence that prompts an organism to seek out externally rewarding experiences, thus this factor was termed

Seeking. Finally, the third factor was made up of agreeableness, conscientiousness, positive affect, and reward responsiveness. This factor was largely composed of measures that suggest happiness and/or contentment. This suggests that this constellation of measures could serve to influence an organism to maintain their current environment, and was termed Maintenance.

This three factor solution is a departure from most of the previous models of latent personality structure, which show a predilection to two factor orthogonal solutions. As reviewed previously, both Eysenck (1967) and Gray (2000) proposed neurobiological personality theories largely focused on two orthogonal factors, although Eysenck and Eysenck (1985) later expanded his model to include a third, ill-defined Psychoticism factor. Eysenck's Extraversion and Neuroticism factors hold similarities to two of the current latent factors related to behaviors focused on seeking external sensation and suppression of behavior. Similarly, Gray's (2000) model of Anxiety and Impulsivity factors are implicated in the seeking and suppression factors, through bottom-up influences on behavioral approach and avoidance behaviors. Finally, the Five-Factor Model has shown a consistent two higher-order factor structure of Stability (or α), consisting of Agreeableness, Conscientiousness, and reversed Neuroticism, and Plasticity (or β), consisting of Extraversion and Openness/Intellect (Jang et al., 2006). It is theorized that these meta-traits are linked to neurochemical functioning with Stability related to serotonin and Plasticity to dopamine (DeYoung, 2006; DeYoung et al., 2002; Yamagata et al., 2006), again suggesting a bottom-up influence on seeking external activation (Extraversion, Plasticity, Impulsivity, dopamine) and avoiding/inhibiting behavior (Neuroticism, Anxiety, Stability, serotonin).

However, the third factor from the current study does not fit neatly into any of these three major neurobiological theories. Each of these models is closely related to this concept of a two-dimensional approach and avoidance structure, related to animal behavior studies that suggest that organisms are influenced along these dimensions, which influence behavioral tendencies to seek external stimulation or a tendency to avoid external events. Perhaps each theory used an overly constricted definition of personality which resulted in the two factor findings. As factor analysis structure is a creation, based on the interrelationships among entered variables, the widening of the variable selection by cutting across theoretical constructs in the current study could be the reason for the disparate finding. The variable makeup of the third factor suggests the additional motivating factor of contentment. If an organism was content with the current makeup of environmental and internal stimuli, that organism might neither seek external stimulation or new experiences, nor avoid stimuli that occur. This contentment influence would suggest a behavioral tendency to avoid major changes while approaching only those rewarding stimuli that have become expectations. Such a tendency could represent an influence on maintaining the status quo and well-established behavior patterns.

This third factor makes sense from an evolutionary/conservationist view. When an organism has successfully expended resources to adapt to its current environment, it would no longer need to expend energy and invite risk seeking additional stimulation and/or behave to avoid expected negative events. The high level of positive affect may represent the emotional expression of this adaptation and the removal of further struggles to adapt. This may also lead to agreeableness and development of high responsivity to expected rewards (although one could also argue that this high responsivity might predispose one to rapid adaptation to rewarding events and contentment). Finally, an organism with well-established behavior patterns may be more conscientious in its performance of these behaviors than organisms that have not developed well-defined behavior patterns, not just in the actual completion of the items, but in the overall motivation to continue current behavior patterns.

Directions for Future Research

There was some crossover from loadings among the second and third factors from positive affect, BIS, BAS reward responsiveness, and to a lesser extent intellect/openness to experience. This suggests that perhaps behavioral inhibition, reward responsiveness, and positive affect are not specific to the identified factors, or that some underlying influence, such as dopaminergic and/or serotonergic functioning, influences more than one of the identified factors. Further research is needed to identify additional or more specific ways of measuring this factor and to provide replication of the emergence of this factor from additional samples. Limitations of the current study include the restricted sample comprised of young adult undergraduate participants. It may be that this three factor structure would show widely different loadings among a more diverse sample in age, ethnicity, and/or education, or that a completely different factor structure would emerge.

This study provided an identification of a factor structure to allow for data reduction for the larger multivariate follow up study. However, their remained the need to validate the cognitive neuroscience tasks for differential engagement of cognitive control and affective responding. Thus, the next study was undertaken to provide this methodological validation.

Chapter 3: Task Related Electrophysiology Responses

Literature Review

Neuropsychological theorists have proposed a distinction between executive functions involving incentives and motivation and those that are engaged by other goal directed motivations (Zelazo & Müller, 2002). The incentive and motivation related executive functions have been termed "hot" executive functions and are related to emotion regulation networks (Zelazo & Müller, 2002). These emotion regulation circuits involve the lateral orbitofrontal and ventromedial frontal cortices, and include connectivity to limbic and paralimbic structures including the anterior cingulate cortex, hypothalamus, hippocampus, insula, and amygdala (Davidson, Jackson, & Kalyn, 2000; Davidson, Putnam, & Larson, 2000). In this conceptualization, the anterior cingulate cortex is thought to mediate top-down affect regulation due to the interconnections with the limbic structures previously reviewed in this work (Chapter 1). The other executive functions include those such as attention, working memory, planning, and inhibition and are associated with more dorsal frontal structures including the dorsolateral frontostriatal and frontoparietal networks (Rubia, Smith, Taylor, & Brammer, 2007). In general, these more dorsal areas of the prefrontal cortex are thought to exert top-down cognitive control through regulating attention, working memory, cognitive flexibility, and inhibitory control of action selections (Fuster, 2001).

This conceptualization is important in electrophysiological studies of cognitive and affective control, as the engagement of either the more cognitive-prefrontal or the affective-orbitofrontal system may result in widely divergent regulation strategies. When applied to the overall statistical decision making model reviewed previously, the overall engaged regulation strategy would ultimately influence the decision making process through subjective value, or the relative costs and benefits of each outcome. This subjective value information is thought to represent individual, subjective influences on the entire process, by directly moderating the probabilities, making possible outcomes with high subjective value (high reward or loss avoidance) more likely through an effort to maximize the overall attained value of decisions (Green & Swets, 1966). In this model, the engagement of the cognitive or affective regulatory systems may cause divergence in how an individual perceives a stimulus, ultimately resulting in different coding of the subjective value. However, this coding is rarely thought of as occurring within a vacuum, but embedded within the context of an individual's goals, which drives the individual decision making process toward goal attainment or optimal responding (Gold & Shadlen, 2007).

Studies linking human decision making utilizing subjective value with physiological processes are severely limited, as there is little overall information about how subjective value is represented in neurophysiological measurements (Gold & Shadlen, 2007), making it difficult to integrate neurological and statistical decision making theories. However, some neurons in the orbitofrontal cortex are thought to directly code independent value (Padoa-Schioppa & Assad, 2006), and some in the ACC are thought to code negative value (Gehring & Willoughby, 2002, Yeung & Sanfey, 2004), either implicating both areas in the overall decision making process, or highlighting their role in coding values in tasks that engage areas involved in emotion regulation.

Early studies investigating the ERN and FN components supported this ACC coding of negative value in the form of coding of overall valence and not magnitude (Gehring et al., 1993; Holroyd & Coles, 2002; Miltner et al., 1997; Nieuwenhuis et al., 2004), but supporting the components as a feedback element in the decision making process. This has been shown in a variety of different tasks, beginning with performance feedback in a time estimation task

(Miltner et al., 1997), and extending to gambling tasks (Gehring & Willoughby, 2002), allowing easy manipulation of reward magnitude coding and not simply binary feedback of performance. Some studies failed to find monetary reward variation reflected in the FN using large and small wins and losses (Hajcak, Moser, Holroyd, & Simons, 2006; Yeung & Sanfey, 2004) or stepped increases in losses (Sato, et al., 2005). Other studies have shown magnitude effects to reward value manipulation when expectancy is taken into account (Bellebaum, Polezzi, & Daum, 2010; Goyer, Woldorff, & Huettel, 2008; Kreussel et al., 2012; Philiastides, Biele, Vavatzanidis, Kazzer, & Heekeren, 2010; Yu & Zhou, 2009).

FN responses to reward probability have been found in a reinforcement learning task with outcome cues (Holroyd & Coles, 2000) and a time estimation task with behavioral adjustment to unexpected outcomes (Holroyd & Krigolson, 2007), both assuming participant rational expectations based on reinforcement information. Hajcak and colleagues (2005) varied probability in a gambling task with reward likelihood cues, but failed to find FN modulation across different probabilities. In a follow up study, Hajcak and colleagues (2007) included trial-by-trial expectation feedback from the participants and found biases in subjective reward expectation from the actual objective probabilities, but no variation of FN, unless the subjective estimate of reward was made following response choice but prior to feedback, where FN amplitudes were greater for unexpected losses. Further studies found small effects for extreme probability variations, and associative learning of probabilities instead of cues (Holroyd, Krigolson, Baker, Lee, & Gibson, 2009). However, large effects were obtained in the same study when participants were forced to learn an optimal response strategy and not just responding within static outcome probability variations. FN amplitudes have also been shown to be reduced in tasks where the participants simply viewed feedback delivery without involvement in response choices, suggesting that the FN reflects attempts to utilize feedback, not just a reaction to reward delivery (Yeung, Holroyd, & Cohen, 2005). Later studies have found that expectancy differences are reflected in the FN when actual optimal response strategies can be learned (Bellebaum & Daum, 2008; Bellebaum et al., 2010; Kreussel et al., 2012), and that FN codes all three dimensions (valence, magnitude, and probability; Bellebaum et al., 2010; Kreussel et al., 2012).

When looking at the neurobiological basis of value based decision making, the subjectivity of outcome becomes important, as objective reward value and subjective value may not be identical (Hajcack, Moser, Holroyd, & Simons, 2007), which is a common assumption among reinforcement learning models (Barto, Sutton, Watkins, Gabriel, & Moore, 1990; Philiastides et al., 2010). However, value in the general statistical decision making models reflects subjectivity and is an additional input besides simple probability. Also, suboptimal responding may be adaptive in certain competitive activities to outsmart opponents or it may facilitate exploration for finding even more optimal response options that are yet unknown (Gold & Shadlen, 2007). There is considerable evidence that gambling tasks inspire a high level of subjectivity through use of fallacious reasoning and beliefs, directly involving the ACC (Campbell-Meiklejohn, Woolrich, Passingham, & Rogers, 2008; Ferland, Ladouceur, & Vitaro, 2002; Fischhoff, Slovic, & Lichtenstein, 1977; Gilovich, 1991; Ladouceur et al., 2001; Rogers, 1998; Sundali & Croson, 2006; Toneatto, 1999).

In a recent study in our own laboratory (Highsmith, Wuensch, Tran, & Everhart, *in preparation*) participant expectancy was induced through use of a response-pattern learning task, where response pattern learning feedback represented higher expectation of negative feedback and responses following pattern acquisition represented lower expectation of negative feedback. Contrary to findings in previous gambling based studies, valence feedback elicited a significant

FN response, while different expectancy conditions showed non-significant FN variation. Negative feedback in this task design was an objective signal that response strategies must be changed in order to maximize winnings in both expectancy conditions. This suggests that the FN in this case was a signal of the need to change planned responses and not primarily responding to feedback expectancy. FN differences between pattern response learning and cue driven gambling tasks could be due to the engagement of different attentional sets, with gambling type tasks inspiring use of non-rational coding of value and affective responses. This suggests that the gambling type task could have engaged the emotion regulation, orbitofrontal-limbic system in the overall control of responding more so than the cognitive, prefrontal-striatal systems.

Presumably, evidence of this could be reflected in trial-by-trial autonomic reactivity data. Gambling behavior has consistently been shown to cause changes in autonomic reactivity when comparing wins and losses (Lole et al., 2012). The previously described pattern learning task was designed to be affectively neutral, limiting affective responses. However, some significant linear reduction in overall mood was reported by participants across all trial blocks, even though losses were rare events in the design. Collecting heart rate variability (HRV) as a measure of autonomic response to a task may allow the direct comparison of a pattern learning and a gambling task to identify if the tasks results in different patterns of HRV oscillations, and presumably, differences in sympathetic and/or parasympathetic responses to the tasks. If different patterns are found, this could reflect differential engagement of attentional set in decision making, with gambling tasks resulting in more LF HRV oscillations to reflect increased sympathetic nervous system responses.

- *Hypothesis 2 – FN responses between pattern response learning and cued probability based tasks will differ and relate to measures of heart rate variability, with lower frequency* *modulation of heart rate suggesting sympathetic nervous system activation and presumed greater affective responses for gambling tasks.*

Participant Recruitment and Screening

In order to confirm elicitation of cognitive and affective responses to primary tasks employed in later studies, 21 healthy, adult undergraduate participants with ages ranging from 18 to 20 years (*M* = 18.76 years, *SD* = 0.7 years) were recruited from the psychology department participant pool and provided class credit for participation (12 women, 9 men). Previous research on within-subject FN *t*-tests in our laboratory suggested that effect sizes for primary analyses would be between *d* = 0.60 and *d* = 0.72, thus sample size estimates were based on an effect size of *d* = 0.65. A-priori power analyses indicate that a sample size of 21 would be necessary to detect differences with α = .05 and β = .80, as shown in Figure 3.

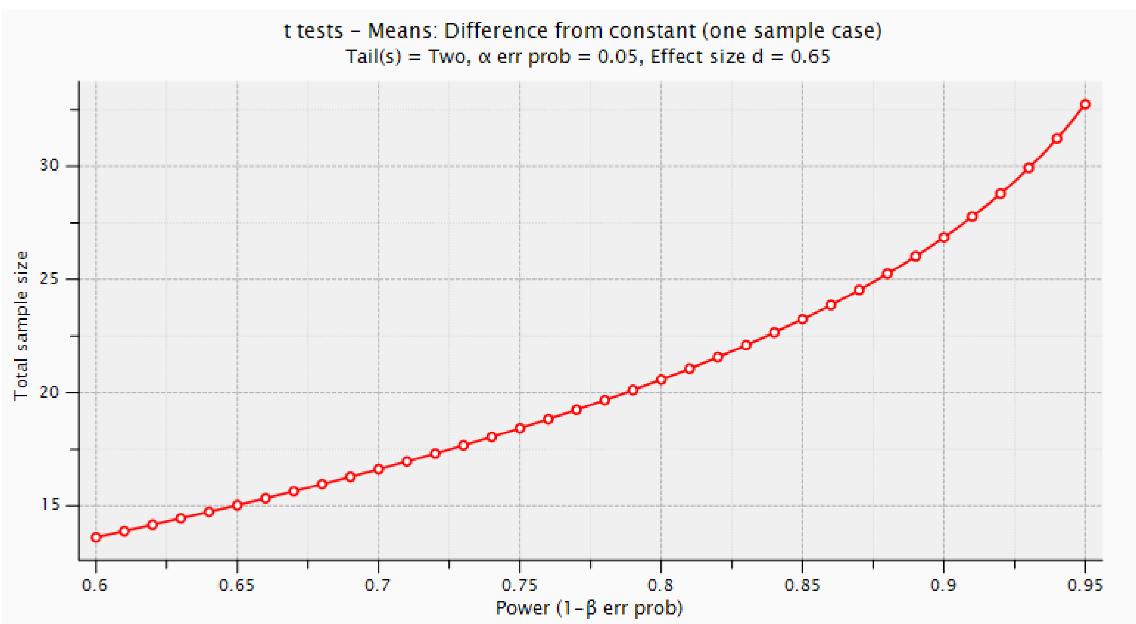

Figure 3 - G*Power A-priori Power Analysis of One-Sample *t*-test

All participants were right-handed and screened for normal or corrected-to-normal vision, with no history of neurological or psychological disorders, current daytime somnolescence or disturbed sleep the night before reporting for the study, or reported use of any substance that might interfere with alertness or electrophysiological measurement. In order to limit any influence of monetary remuneration on participant selection, participants were informed that they would be receiving both cash rewards based on performance and entry into a raffle for a $50 cash prize after disclosing no disqualifying information. All participants provided written informed consent prior to the start of the study and the study was approved by the University and Medical Center Institutional Review Board (UMCIRB), prior to initiating screening procedures (Appendix A).

As the experimental procedures included gambling behavior, all participants were screened for problem gambling behavior with the South Oaks Gambling Screen (SOGS; Lesieur & Blume, 1987), using the standard cutoff of 5 as an exclusion criterion. Participants reported very little gambling behavior (Mean score = 0.19, *SD* = 0.51), with only three participants reporting any previous gambling behavior, with the maximum value reported of 2 points. Due to the extremely low reporting of gambling behavior amongst the sample, SOGS scores were removed from later analyses.

Experimental Procedure

Cognitive task. Participants were presented two separate tasks using similar stimuli to attempt and differentially engage affective responses to the tasks, cross lagged across participants. The cognitive task consisted of a similar procedure utilized to limit participant affective responses reported in Highsmith et al., (in preparation). Participants were briefed regarding the experimental procedures and received verbal motivation to maximize winnings, as total points determined raffle entries for the $50 gift card. Participants were explicitly told that the correct choices were not random, but came in four different two card left and right patterns

(LL, RR, LR, and RL), and to maximize winnings, these patterns must be guessed and repeated, but patterns would shift after every four responses. Following preparation for psychophysiological recording, participants were seated in a comfortable chair in a dimly lit acoustically shielded room approximately 1m from a LCD stimulus display. Participants were instructed to limit movement and undergo baseline recording procedures. All responses were collected using a four key stimulus keypad, held in both hands, with thumbs used for responses. For the current task, participants were instructed to use the thumb of their left hand to select the left card and the thumb of their right hand to select the right card on the outermost two keys. Participants were given the opportunity to conduct two practice series to familiarize them with the game, consisting of two set correct response patterns (LL and RR).

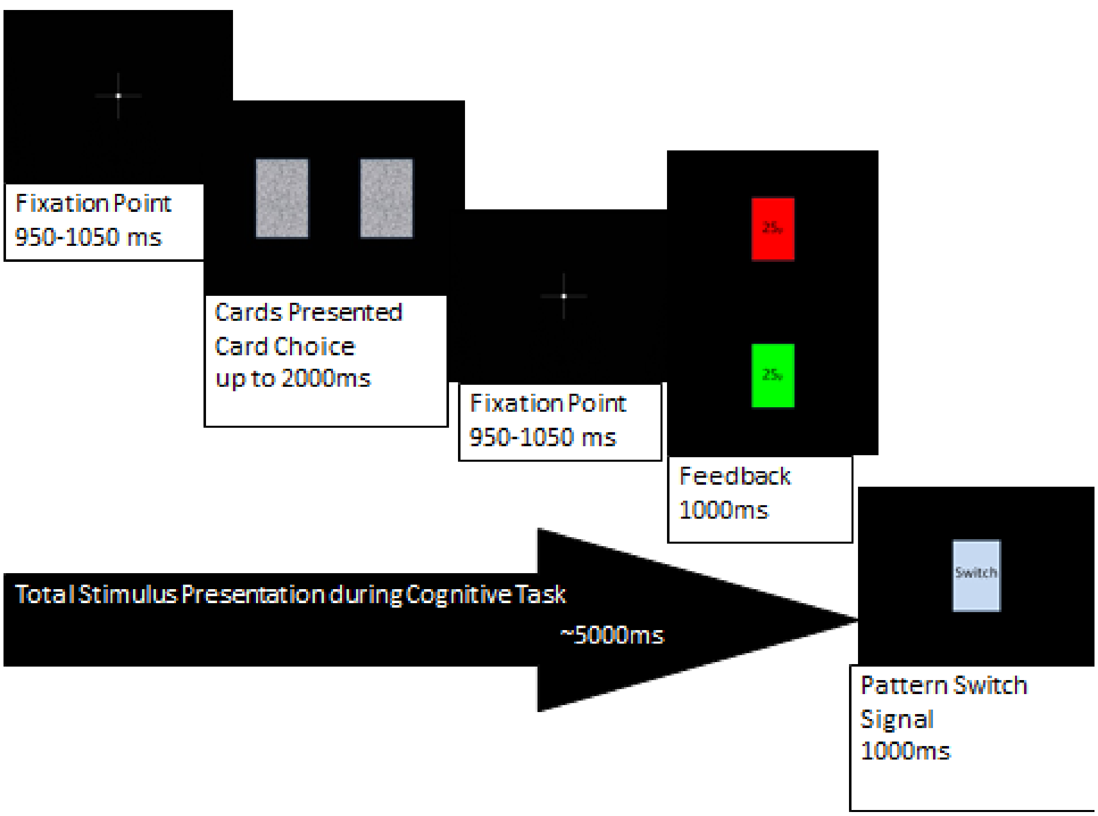

Figure 4 – Cognitive Task Stimulus Presentation

Each trial totaled five seconds in length, as shown in Figure 4, and began with fixation followed by presentation of two textured rectangles (roughly representing a playing card) equally spaced horizontally on the LCD screen, remaining until participant selection. Selection removed the cards and presented a fixation cross for a random inter-stimulus interval between 950 and 1050ms, followed by a feedback rectangle presented for one second, centered on the LCD screen, filled green for win and red for loss with the number of points won or lost centered in the middle of the rectangle (fixed at 25). Response pattern shift was directly signaled between trials. Each presented pattern consisted of a two trial learning phase and a repetition of the correct pattern across the next two trials, totaling approximately twenty seconds for each pattern presentation. Participants completed thirty randomly determined patterns across approximately a ten minute period. Specific program code utilized is shown in Appendix C.

FN measures were computed as differences in loss and win feedback averages across all presented feedback for each scalp electrode. Total cognitive task autonomic response was taken from HRV measures by computing LF, HF, and LF/HF ratio power collected between two and seven minutes during task commission. Correct behavioral adaptation was computed as the total number of behavioral corrections following negative feedback from the initial two trial phases.

Gambling task. Stimuli and procedures for the gambling task were nearly identical to the cognitive task. Participants were told that the correct choices on this task were randomly determined and the participant must simply guess the correct card on each trial. Participants were again instructed to limit movement and response selection was identical to the cognitive task. Each trial again totaled five seconds in length, as shown in Figure 5, with the only differentiation between the cognitive task being monetary rewards and losses conferred on each trial, again represented with green and red centered rectangles, this time containing the value of the monetary reward (25¢). Participants were provided with a one dollar total at the outset of the task, and provided feedback after each four guesses with the total monetary value of their winnings/losses.

Participants were presented with 120 response choices across approximately a ten minute period. Specific program code is shown in Appendix C. FN measures were computed as differences in averages between the loss and win feedback processing responses across all presented feedback. Total gambling task autonomic response was computed using LF, HF, and LF/HF ratio power collected between two and seven minutes during task commission. Although there is no absolute correct behavioral adaptation to feedback, as correct responses were randomly generated for each response, measures of overall behavioral adaptation were computed across trails as the total number of incongruent responses after negative feedback (picking other response option following loss) minus the number of congruent responses after negative feedback.

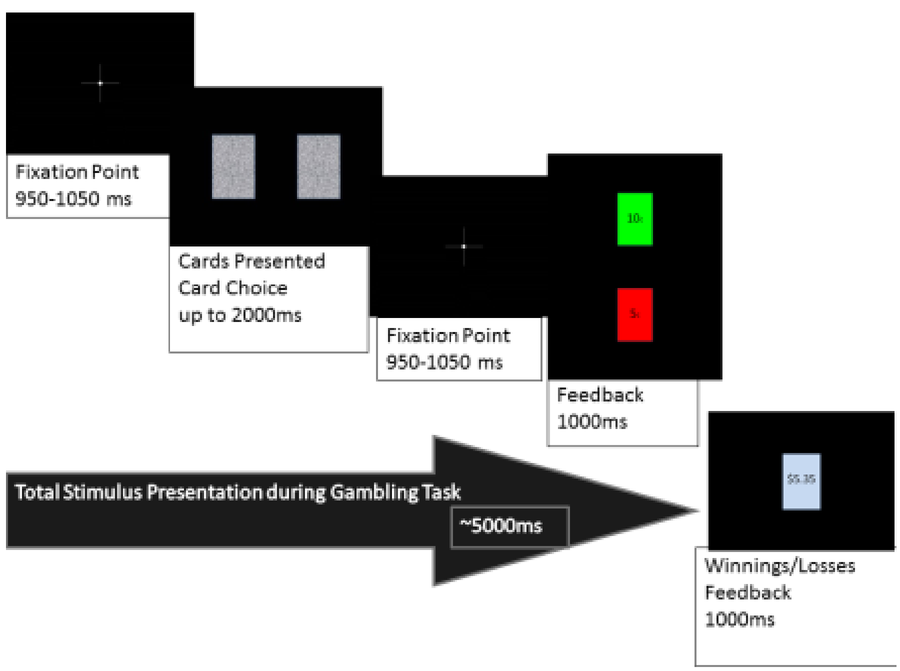

Figure 5 – Gambling Task Stimulus Presentation

Also, deviation from random responding was computed as the inverse of the absolute value of differences between left and right response choices, assuming that random responding should roughly equate to 60 responses per option, and deviation from this would represent lateral response bias.

General Procedures

Recording overview. Scalp electrical activity was recorded using Ag/Ag Cl - sintered electrodes mounted in a neoprene Quik-Cap (Compumedics Neuroscan; Herndon, VA) at 32 scalp sites using the international 10/20 placement system (Fp1, Fp2, F7, F8, F3, F4, FT7, FT8, FT9, FT10, T3, T4, FC3, FC4, C3, C4, CP3, CP4, TP7, TP8, T5, T6, P3, P4, O1, O2, Fz, FCz, Cz, CPz, Pz, Oz). A ground electrode was placed on the frontal midline anterior to electrode Fz, and referenced to linked ears (A1-A2/2). The impedance of all electrodes was maintained at less than 5 kΩ prior to acquisition. Eye blinks and Electro-ocular (EOG) activity was acquired continuously and simultaneously using pairs of Ag/Ag Cl – sintered electrodes near the lateral canthus of each eye for EOG measurement, and placed superior and inferior to the midline of the left eye for eye blink measurement. All measurements were acquired using a 40-channel NuAmps DC amplifier and NEUROSCAN ACQUIRE 4.4 (Compumedics Neuroscan), using a 1024 Hz sampling rate within the 0.1-50 Hz frequency band. EOG and eye-blink ocular artifact reduction were performed offline using a multiple-lag time domain regression analysis (Kenemans, Molenaar, Verbaten, & Slangen, 1991; Verleger, Gasser, & Möcks, 1982).

Autonomic responsivity. Measures of heart rate variability (HRV) were acquired simultaneously with EEG recording to provide estimates of autonomic nervous system regulatory balance, with 5 minutes of baseline HRV taken at baseline, with an additional 5 minutes collected during performance of each of the ERP tasks, taken between minutes 2 and 7 of task performance. Electrocardiographic (ECG) measures were collected using three Ag/Ag-Cl -sintered electrodes placed bilaterally on the participants' wrists. All measurements were recorded using a BIOCOM 3000 ECG system and Heart Rhythm Scanning Software (Biocom technologies, Poulsbo, WA). Frequency domain spectral data was extracted using a Fast Fourier Transformation (FFT) procedure. Frequency band was defined using standard frequency oscillation ranges with Low Frequency (LF) band defined between 0.04 and 0.15 Hz and the High Frequency (HF) band between 0.15 and 0.4 Hz (Task Force, 1996). In addition, LF/HF ratios were calculated for each short-term recording, with higher values representing sympathetic system domination and higher affective responses to task. Pilot data collected prior to experimental procedures suggested that minor muscular artifact associated with response selection did not interfere with ECG recording.

ERP measures. ERPs were extracted from continuous measurements using 1100ms epoch windows, including a 100ms pre-feedback baseline and the 1000ms following feedback presentation following eye-movement correction identical to baseline frontal alpha asymmetry processing. All files were digitally filtered using a 6 dB band-pass filter (0.1 to 100Hz) and baseline corrected relative to the 100ms pre-feedback baseline. Grand average waveforms were averaged from total loss and total win feedback across all trials and conditions for the FZ, CZ, and PZ electrodes (Figure 6). Overall difference waves (Figure 7) for each electrode revealed a negative deflection in the wave between 225 and 325 ms, distributed fronto-centrally and consistent with a FN component (Figure 8). Dipole source localization of the difference waves for the 250-275 ms time window suggest the ERP was generated in the anterior cingulate cortex (Figure 9).

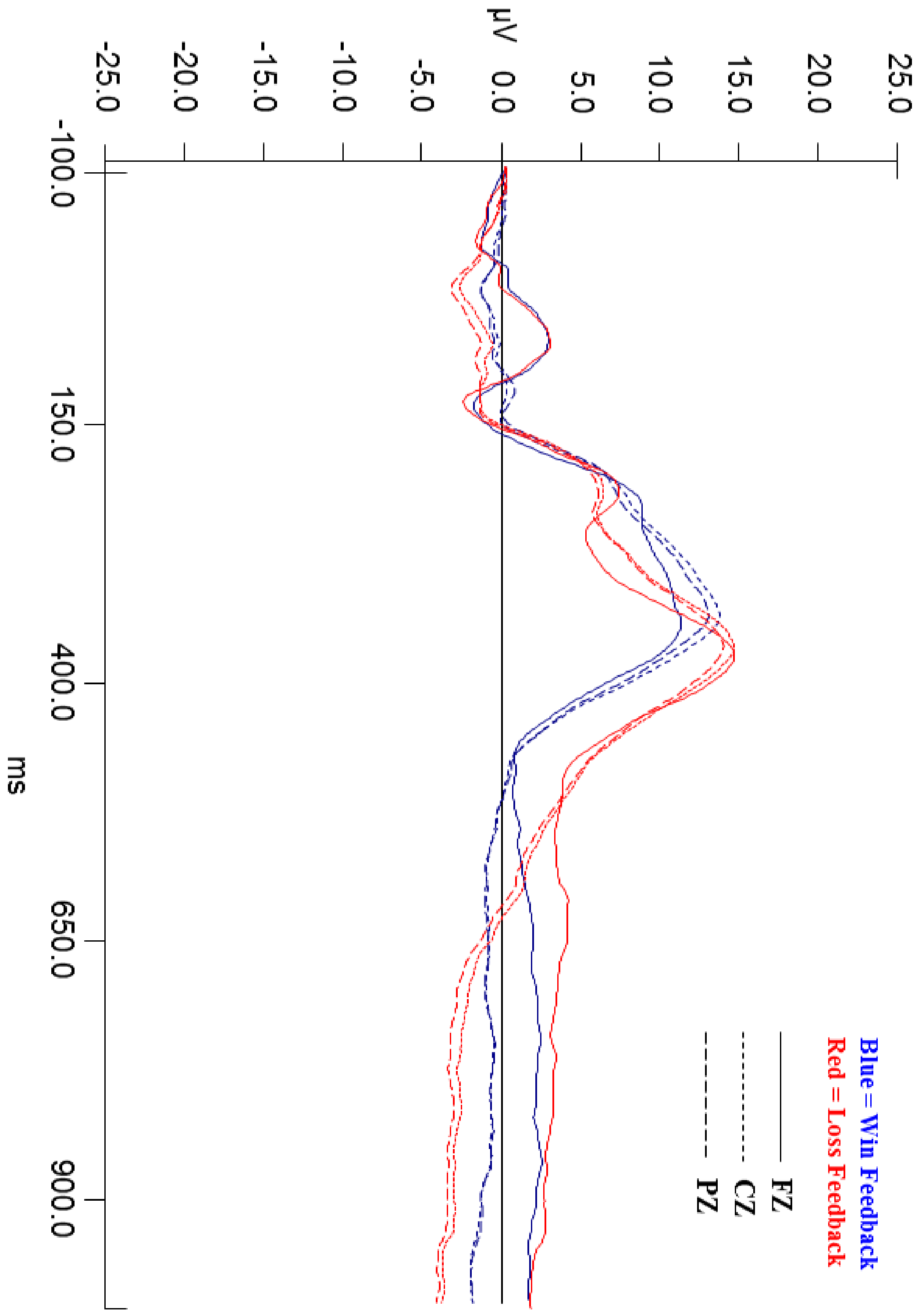

Figure 6 – Grand Average Waveforms

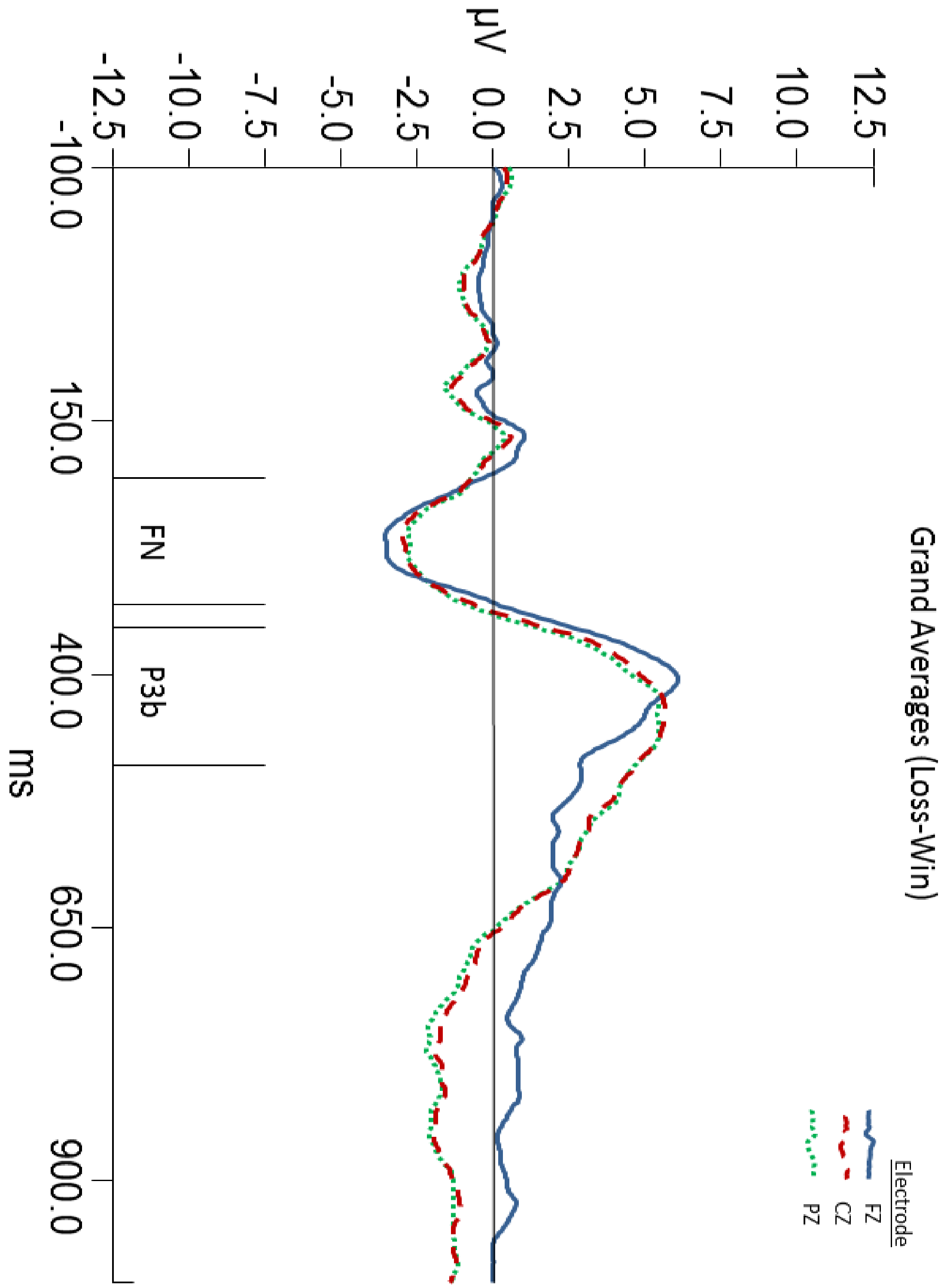

Figure 7 – Grand Average Difference Waveforms

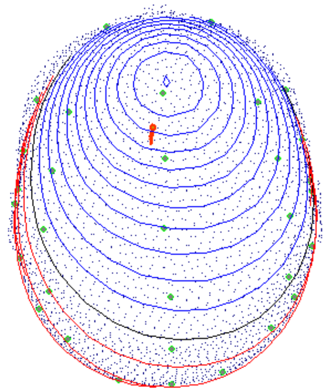

Figure 8 – Modeled Spatial Distribution of FN Component at 250ms (Anterior up)

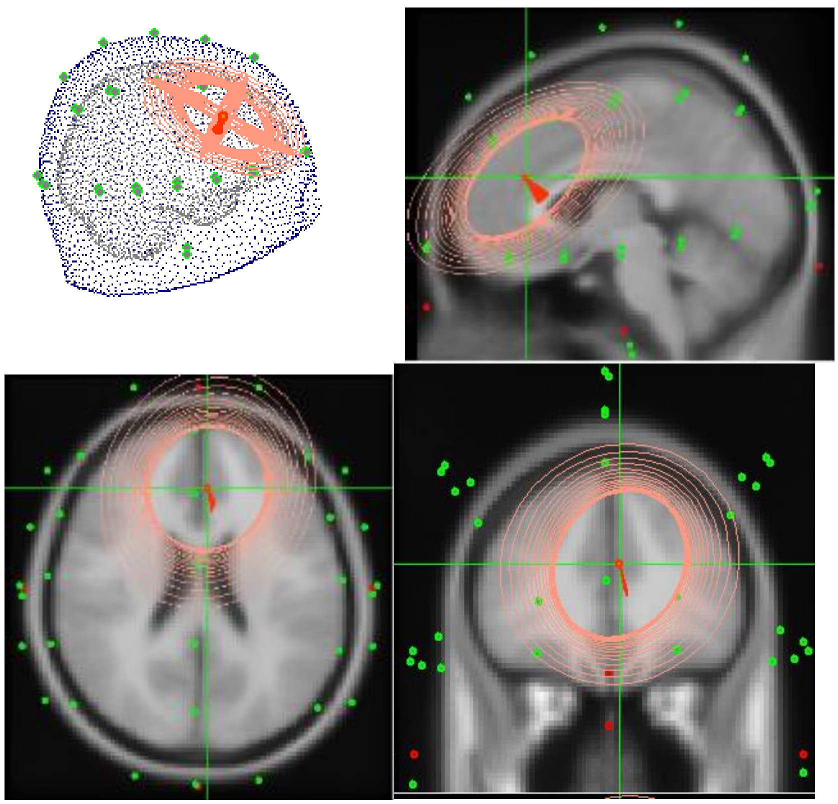

Figure 9 – Dipole Source Localization of FN ERP in the 250-275 ms Time Window

In addition, a significant positive deflection occurred between 350 and 450 ms, distributed parieto-centrally, which was consistent with a P3b novelty response (Figure 10). Dipole source localization of the difference waves for the 375-425 ms time window suggest the ERP was generated in the anterior cingulate cortex (Figure 11). FN amplitudes were extracted as the most negative peak in the 225 and 325 ms time window and computed as a difference score between the loss and win feedback peaks extracted for each electrode and task condition. P3b amplitudes were similarly extracted as the most positive peak in the time window between 350 and 450 ms and computed as the difference score for each electrode and task condition.

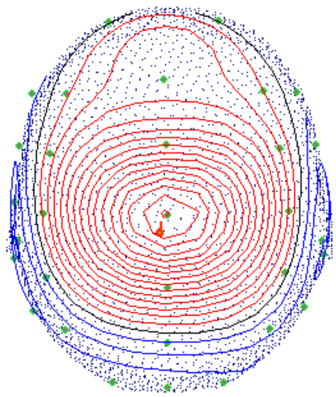

Figure 10 – Modeled Spatial Distribution of P3b Component at 400ms (Anterior up)

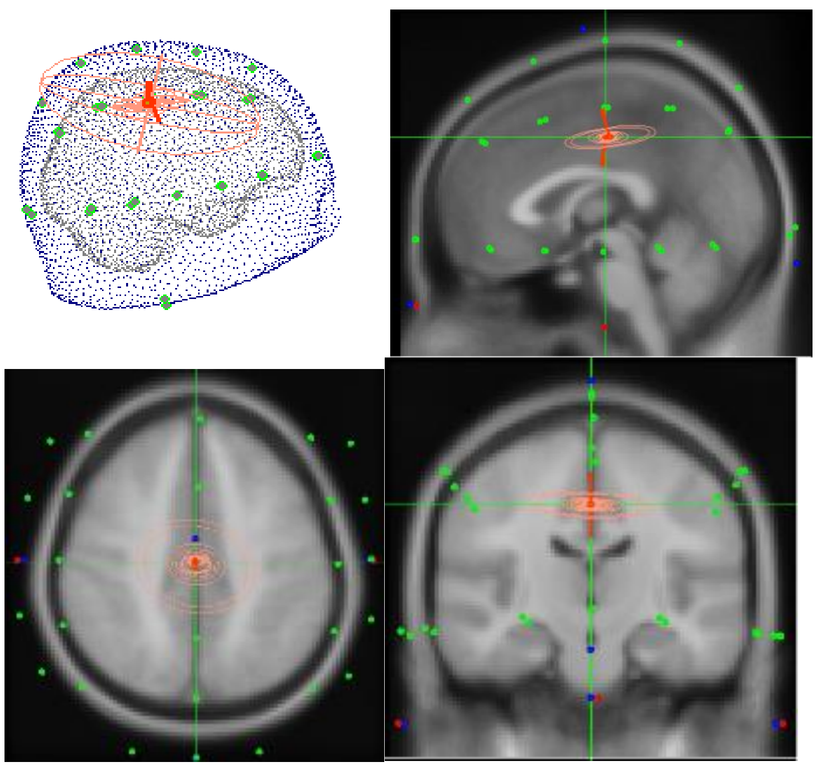

Figure 11 – Dipole Source Localization of P3b ERP 375-425ms Window

Results

Participant demographics. A total of 12 women and 9 men participated in the current study. Participants reported between 12 and 13 years of education (M = 12.24 years, SD = .436 years), which was significantly positively correlated with age, r = .522, p = .015, as is expected of a college sample. Of note, point biserial correlations showed that gender (coded 0 = W, 1 = M) was significantly positively correlated with level of education, r = .549, p = .010, and age, r = .724, p < .001, suggesting that men who participated in this study tended to be slightly older with more time in college. Due to the possible gender differences on task responses, additional one-way ANOVA analyses using gender as the grouping variable were planned for primary outcome measures and are reported below.

Behavioral results. An overall ratio of right/left hand responses to the tasks was computed from the recorded responses to look for lateral response bias on the parts of the participants. Ratios ranged from .765 to 1.698 (M = 1.08, SD = 0.25), suggesting a slight preference to respond with the right thumb during the task for the exclusively right handed participants. However, this response ratio was not significantly correlated with response latency, r = -.180, p = .435, or score on the cognitive game, r = .009, p = .971. However, it was found that this ratio was significantly negatively correlated with total score on the gambling task, r = -.598, p = .004, suggesting that participants who tended to show more of a lateral response bias for right-handed responding performed less well on this task than those who had more balanced responding. A one-way ANOVA of R/L ratio between genders was significant, F(1, 19) = 8.214, p = .010, d = 1.31, showing that male participants had more of a response bias for right thumb responses across the study.

Scores from the cognitive game ranged from 400 to 1600 points (*M* = 1164, *SD* = 415). The maximum number of possible adaptations to the game (representing a behavioral correction from loss feedback) was not fixed due to the unpredictable nature of the individuals guesses, but should be near 60 based on the random nature of the game. Correct adaptations ranged from 42 to 60 (*M* = 54.76, *SD* = 6.99) and was somewhat negatively skewed (-0.928). The number of adaptations were significantly correlated with overall score on the cognitive task, $r = .944$, $p < .001$. Due to this significant shared variance, overall scores but not adaptations were used in later analyses. A one-way ANOVA of cognitive scores between genders was not significant, $F(1, 19) = .193$, $p = .665$, showing no gender differences in cognitive scores.

Winnings from the gambling task ranged from -25¢ to $3.75 (*M* = $1.88, *SD* = 96¢). Average response latencies in the cognitive task ranged from 436 ms to 2702 ms (*M* = 1245 ms, *SD* = 526 ms). While there was not true adaptation due to the randomized correct responses, the total number of lateral response shifts following incorrect feedback was recorded for the gambling task. Total lateral shifts ranged from 38 to 56 (*M* = 48, *SD* = 6). These switches were not correlated with score on the gambling task, $r = -.243$, $p = .289$. A one-way ANOVA of gambling task scores between genders was not significant, $F(1, 19) = 3.135$, $p = .093$, showing no gender differences in gambling scores.

Electroencephalographic results. It was hypothesized that both tasks would yield a significant FN response, spatially distributed on fronto-central electrodes. One sample *t* tests on computed loss-win FN amplitude difference scores for the cognitive task were significant for all midline electrodes, including FZ (Figure 12), $t(20)= 2.55$, $p = .019$, $d = 1.17$, CZ (Figure 13), $t(20)= 3.74$, $p = .001$, $d = 1.71$, and PZ (Figure 14), $t(20)= 3.54$, $p = .002$, $d = 1.62$. Similarly, one sample *t* tests on computed loss-win P3b amplitude difference scores for the cognitive task were significant for all midline electrodes including FZ (Figure 12), $t(20)= 9.14$, $p < .001$, $d = 4.19$, CZ (Figure 13), $t(20)= 7.92$, $p < .001$, $d = 3.63$, and PZ (Figure 14), $t(20)= 7.92$, $p < .001$, $d = 3.63$. One-way ANOVA analysis of gender differences in FN amplitude for the cognitive task were not significant for any of the tested electrodes, including FZ, $F(1, 19) = .062$, $p = .807$, CZ, $F(1, 19) = .005$, $p = .943$, or PZ, $F(1, 19) = .160$, $p = .008$. However, similar ANOVA analyses on P3b amplitudes showed significant gender differences at all electrode sites tested, including FZ (Female = 9.62μV, Male = 5.08 μV), $F(1, 19) = 8.631$, $p = .008$, CZ (Female = 9.24 μV, Male = 4.74 μV), $F(1, 19) = 7.776$, $p = .012$, and PZ (Female = 7.76 μV, Male = 4.30 μV), $F(1, 19) = 5.765$, $p = .027$.

One sample *t* tests on computed loss-win FN amplitude difference scores for the gambling task were significant for all midline electrodes, including FZ (Figure 15), $t(20)= 11.69$, $p < .001$, $d = 5.36$, CZ (Figure 16), $t(20)= 10.84$, $p < .001$, $d = 4.97$, and PZ (Figure 17), $t(20)= 10.31$, $p < .001$, $d = 4.72$. Similarly, one sample *t* tests on computed loss-win P3b amplitude difference scores for the gambling task were significant for all midline electrodes, including FZ (Figure 15), $t(20)= 8.55$, $p < .001$, $d = 3.91$, *CZ* (Figure 16), $t(20)= 7.47$, $p < .001$, $d = 3.42$, and PZ (Figure 17), $t(20)= 7.60$, $p < .001$, $d = 3.48$. One-way ANOVA analysis of gender differences in FN amplitude for the gambling task were not significant for any of the tested electrodes, including FZ, $F(1, 19) = 1.383$, $p = .254$, CZ, $F(1, 19) = .422$, $p = .523$, or PZ, $F(1, 19) = .243$, $p = .628$. Similar ANOVA analyses on P3b amplitudes also showed no significant gender differences at any tested electrode, including FZ, $F(1, 19) = 1.197$, $p = .288$, CZ, $F(1, 19) = 2.155$, $p = .159$, or PZ, $F(1, 19) = 1.311$, $p = .267$.

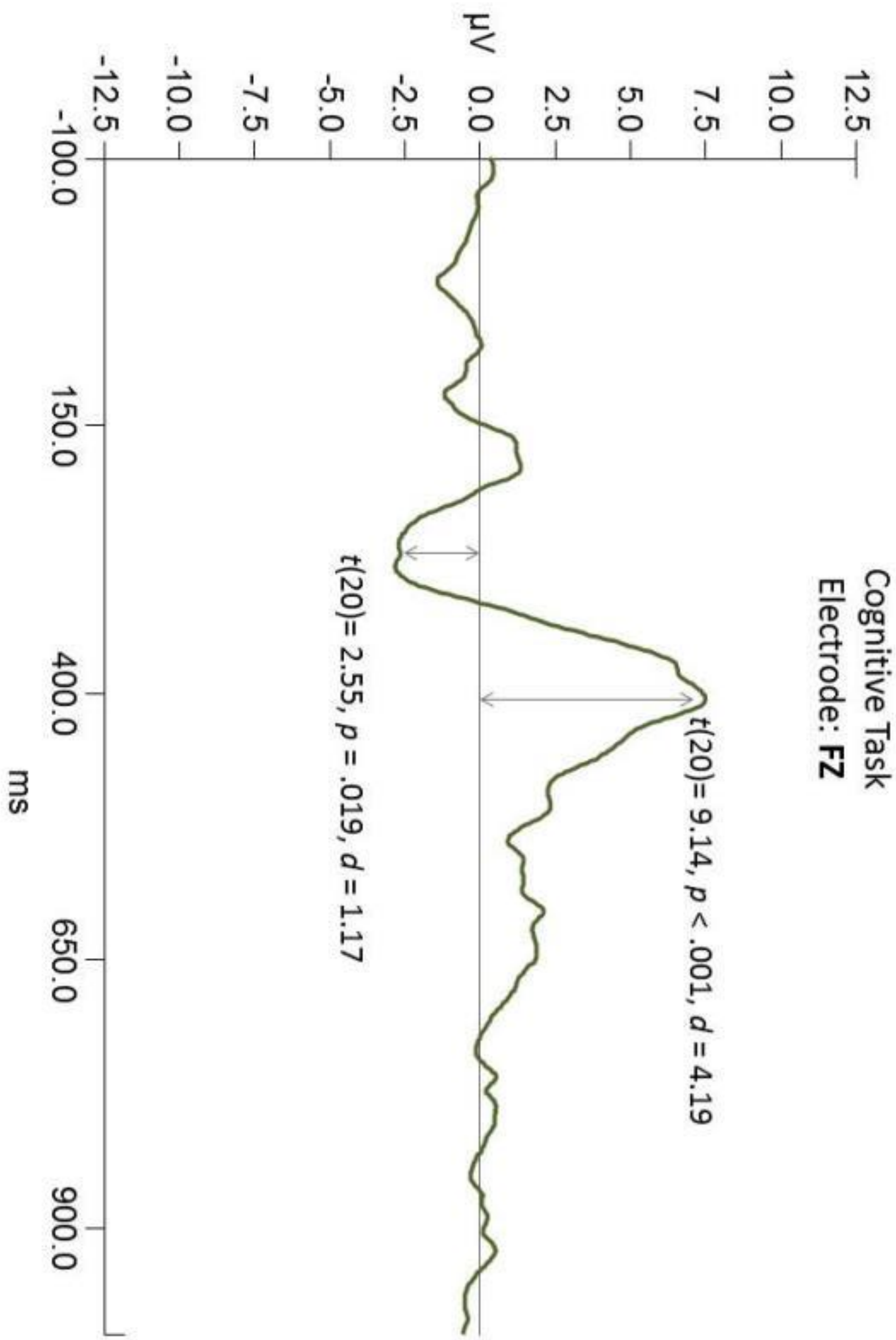

Figure 12 – Cognitive Task Difference Waveform FZ Electrode

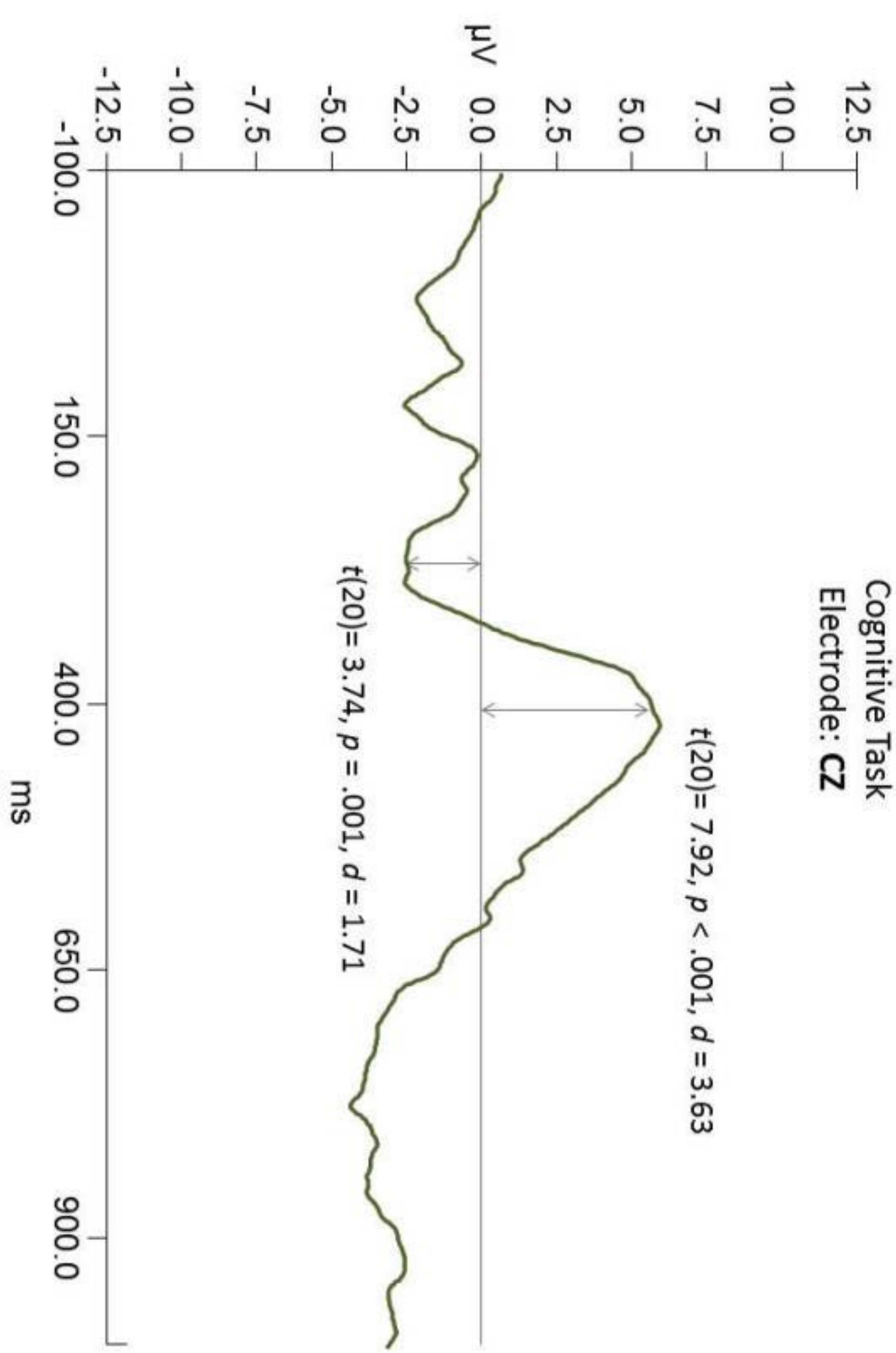

Figure 13 – Cognitive Task Difference Waveform CZ Electrode

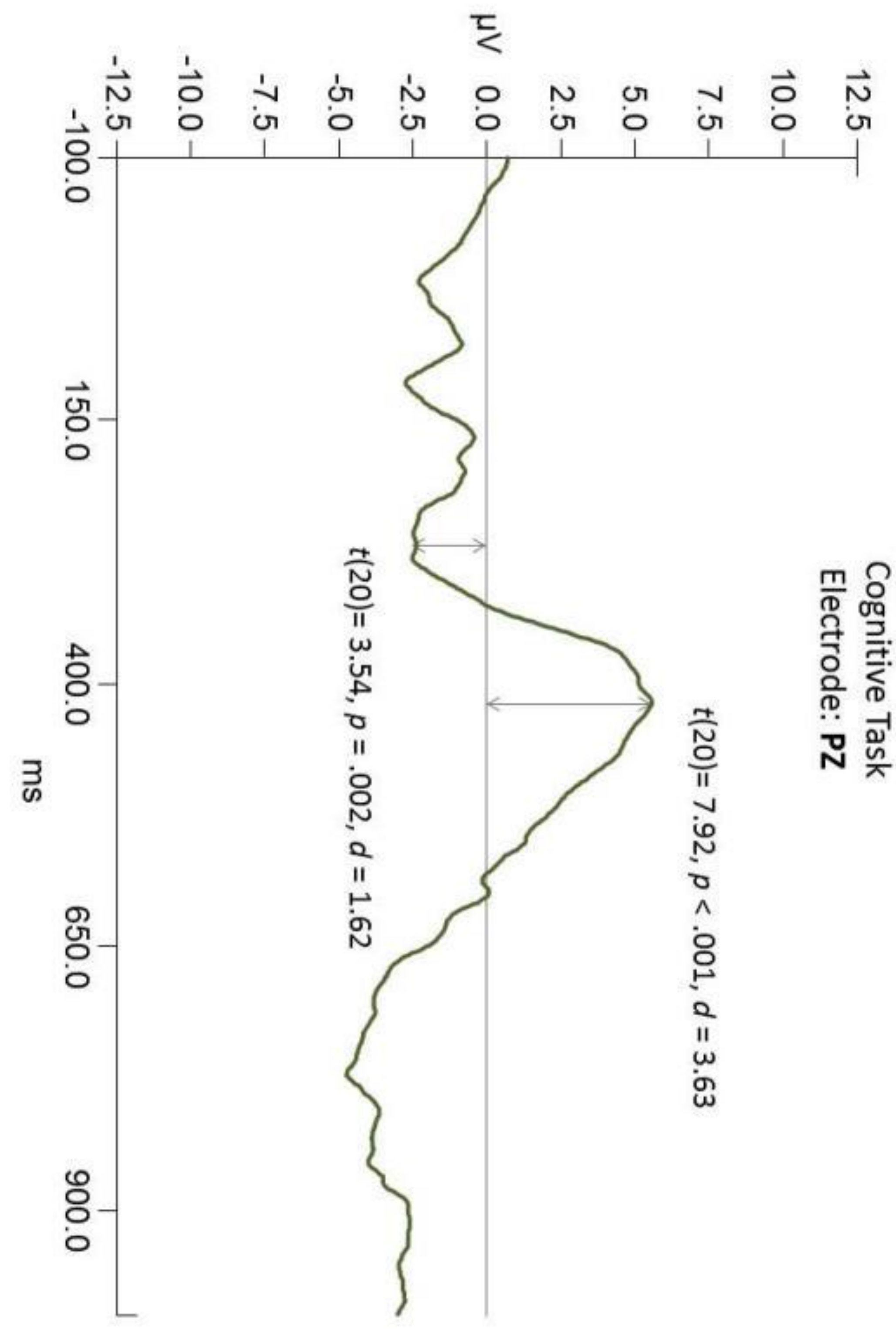

Figure 14 – Cognitive Task Difference Waveform PZ Electrode

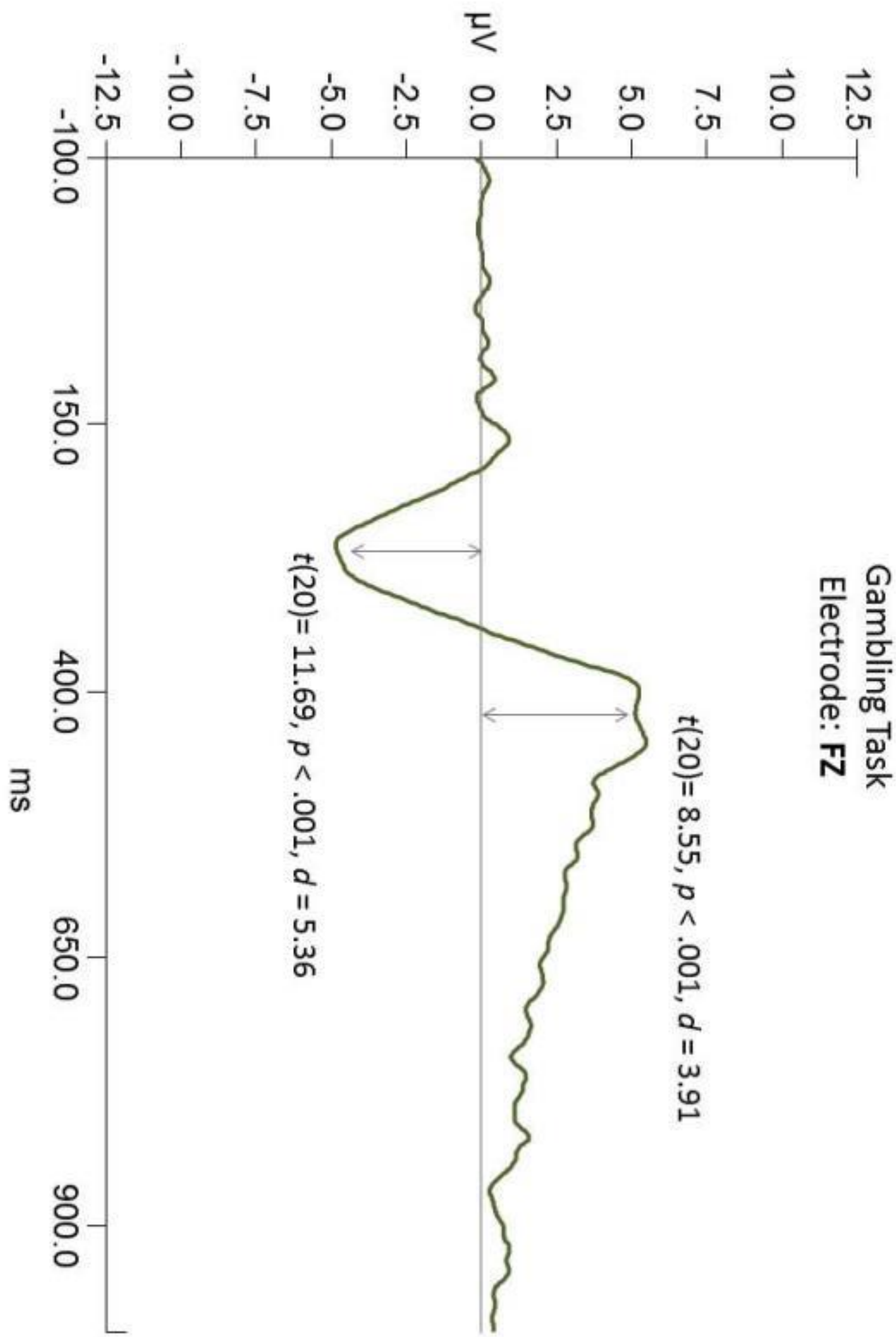

Figure 15 – Gambling Task Difference Waveform FZ Electrode

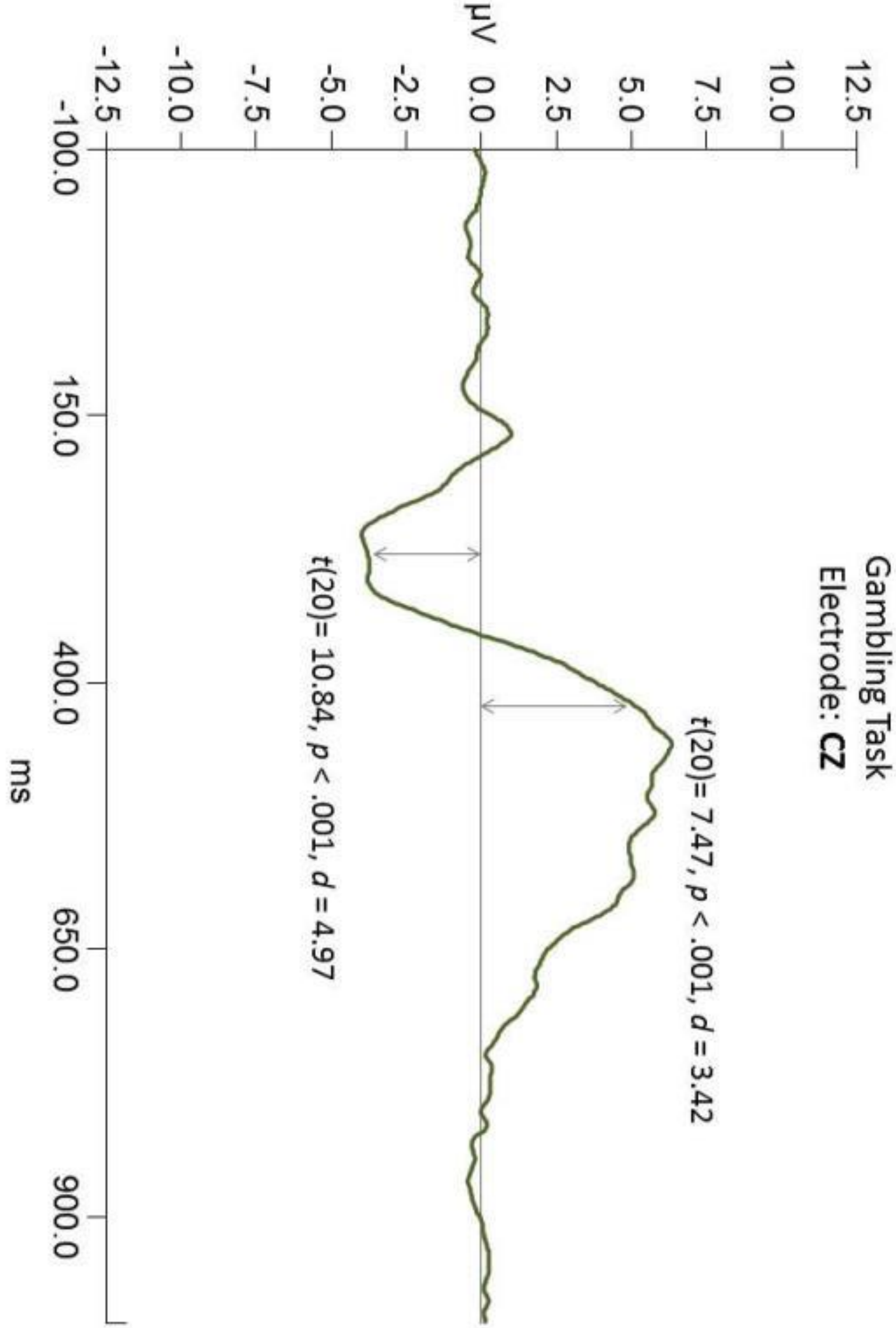

Figure 16 – Gambling Task Difference Waveform CZ Electrode

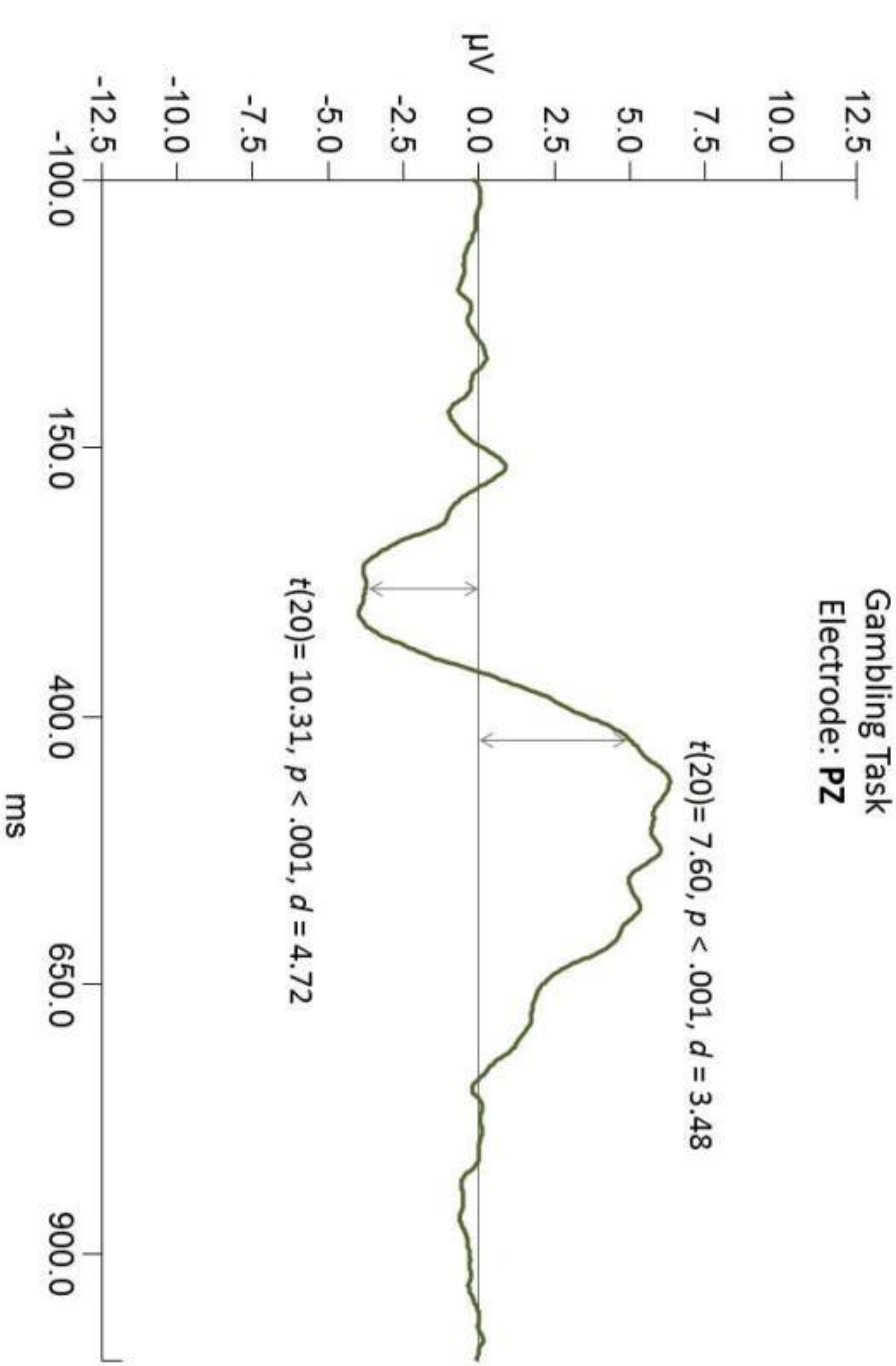

Figure 17 – Gambling Task Difference Waveform PZ Electrode

It was also expected that paired-sample *t* tests on FN amplitudes between task conditions would significantly differ, indicating differing FN responsivity to each condition. FN amplitudes were significantly more negative for the FZ electrode in the gambling task (M = -6.80, SD = 2.66) than the cognitive task (M = -3.14, SD = 5.62), t(20)= -2.83, p = .01, d = 1.30, while differences were not found to be significant for the CZ, t(20)= -1.90, p = .072, d = 0.87, or PZ electrodes, t(20)= -1.25, p = .225, d = 0.57. For the P3b component, no significant differences between tasks were found. No significant latency differences between tasks were found for the FN component. P3b peaks occurred significantly later for the FZ electrode in the gambling task (M = 411.9 ms, SD = 27.9 ms) than the cognitive task (M = 380.67 ms, SD = 40.52), t(20)= 2.92, p = .009, d = 1.34. Similarly, P3b peaks occurred significantly later for the CZ electrode in the gambling task (M = 429.1 ms, SD = 29.4 ms) than the cognitive task (M = 396.2 ms, SD = 50.4 ms), t(20)= 3.21, p = .004, d = 1.48, but no differences were found for the PZ electrode, t(20)= 1.94, p = .066, d = 0.89.

Autonomic responsivity results. Mean baseline LF spectral power was 242 ms^2 (SD = 127 ms^2), with mean baseline HF spectral power of 268 ms^2 (SD = 205 ms^2). Computed LF/HF ratios for the baseline condition had a mean of 1.19 (SD = 0.49). One-way ANOVA of baseline HRV measures by gender found no significant difference for the LF spectral power for the baseline condition (women = 249 ms^2, men = 232 ms^2), F(1, 19) = 0.08, p = .780. However, similar one-way ANOVA for the HF spectral power means found significant gender differences (women = 348 ms^2, men = 162 ms^2), F(1, 19) = 5.062, p = .037, d = 1.03, which were also reflected in the LF/HF ratios, F(1, 19) = 10.186, p = .005, d = 1.25.

Mean cognitive task LF spectral power was 263 ms^2 (SD = 176ms^2), with mean cognitive task HF spectral power of 342 ms^2 (SD = 273 ms^2). Computed LF/HF Ratios for the cognitive task had a mean of 0.848 (*SD* = 0.461). One-way ANOVA of cognitive task HRV measures by order of task administration found no significant effects of task administration order, for either LF, $F(1, 19) = .582$, $p = .455$, HF, $F(1, 19) = 1.477$, $p = .244$, or the LF/HF ratio, $F(1, 19) = 1.323$, $p = .264$. Similar to the baseline findings, one-way ANOVA of the LF spectral power for the cognitive task showed no significant gender differences (women = 227 ms^2, men = 309 ms^2), $F(1, 19) = 1.121$, $p = .303$. However, contrary to the baseline findings, significant gender differences were not found for the HF spectral power in the cognitive task (women = 429 ms^2, men = 226 ms^2), $F(1, 19) = 3.121$, $p = .093$. Cognitive task mean LF/HF ratios showed significant gender differences (women = .657, men = 1.103), $F(1, 19) = 6.007$, $p = .024$, $d = 1.12$.

Mean LF spectral power during the gambling task was 513 ms^2 (*SD* = 221 ms^2), while mean gambling task HF spectral power was 287 ms^2 (*SD* = 155 ms^2). Computed LF/HF ratios for the gambling task had a mean of 1.912 (*SD* = .822). One-way ANOVA of gambling task HRV measures by order of task administration found no significant effects of task administration order on HRV outcomes, for either LF, $F(1, 19) = .241$, $p = .629$, HF, $F(1, 19) = 0.066$, $p = .800$, or the LF/HF ratio, $F(1, 19) = 0.582$, $p = .455$. Similar to the baseline and cognitive findings, one-way ANOVA of the LF spectral power for the gambling task showed no significant gender differences (women = 556 ms^2, men = 456 ms^2), $F(1, 19) = 1.057$, $p = .317$. However, significant gender differences were found for the HF spectral power in the gambling task (women = 363 ms^2, men = 185 ms^2), $F(1, 19) = 9.740$, $p = .006$, $d = 1.44$. Gambling task mean LF/HF ratios also showed significant gender differences (women = 1.543, men = 2.404), $F(1, 19) = 7.453$, $p = .013$, $d = 1.25$.

It was expected that the gambling task would yield HRV measures indicative of greater affective responses than the cognitive task. Paired-sample *t*-tests between baseline and the cognitive task found that scores were not significantly different from zero for LF spectral power, $t(20) = .623$, $p = .540$, but significantly higher HF spectral power for the cognitive task, $t(20) = 2.302$, $p < .032$, $d = 1.03$, leading to significantly lower LF/HF ratios for the cognitive task compared to baseline, $t(20) = 4.880$, $p < .001$. Paired-sample *t*-tests on mean scores between baseline and the gambling task found that scores were not significantly different for HF spectral power, $t(20) = 0.589$, $p = .562$, but there was significantly higher LF spectral power in the gambling task, $t(20) = 6.977$, $p < .001$, $d = 3.12$, leading to significantly higher LF/HF ratios, $t(20) = 6.387$, $p < .001$, d = 2.86.

It was also expected that both LF and HF spectral power between gambling and cognitive tasks would be significantly different. However, paired *t*-tests between cognitive and gambling tasks showed that mean power was not significantly different for HF, $t(20) = 1.072$, $p = .296$. The hypothesis was partially supported, as paired *t*-tests indicated that the total LF power was significantly (+250 ms^2) larger for the gambling task, $t(20) = 5.076$, $p < .001$, $d = 2.27$. It was also hypothesized that LF/HF ratio power would be significantly higher for the gambling task, indicating significantly increased relative sympathetic nervous system activation for the gambling task. Paired sample *t*-tests indicated significantly higher LF/HF ratio for the gambling task, $t(20) = 8.407$, $p < .001$, $d = 3.76$.

Between measure results. It was expected that FN responses for both cognitive and gambling tasks would significantly correlate to measures of HRV for each condition. For the cognitive task (Table 4), there were no significant correlations between FN amplitudes at any of the tested electrode sites and HRV measures. However, two-tailed correlations identified a number of significant relationships for P3b amplitudes. LF spectral power was significantly negatively related to P3b amplitudes for CZ, $r = -.497$, $p = .022$, and at PZ, $r = -.551$, $p = .010$, and trended toward significance for FZ, $r = -.432$, $p = .051$. These relationships were also evident through the LF/HF ratios for all three electrode sites, including FZ, $r = -.444$, $p = .044$, CZ, $r = -.488$, $p = .025$, and PZ, $r = -.455$, $p = .038$. Within the gambling task (Table 5), there were no significant correlations between FN and P3b amplitudes with any of the HRV measures.

Table 4

Pearson Product Moment Correlations between ERP amplitudes and HRV spectral power measures during the cognitive task

ERP	LF	HF	LF/HF Ratio
FN FZ	.094	.120	-.008
FN CZ	.184	-.184	.234
FN PZ	.120	-.217	.213
P3b FZ	-.432	.092	-.444*
P3b CZ	-.497*	.101	-.488*
P3b PZ	-.551**	-.024	-.455*

Note. *= $p < .05$, **= $p < .01$. $N = 21$ for all analyses.

Table 5

Pearson Product Moment Correlations between ERP amplitudes and HRV spectral power measures during the gambling task

ERP	LF	HF	LF/HF Ratio
FN FZ	-.041	-.173	.029
FN CZ	.191	-.125	.183
FN PZ	.030	.107	-.114
P3b FZ	-.060	.201	-.269
P3b CZ	.036	.286	-.276
P3b PZ	.032	.206	-.168

Note. *= $p < .05$, **= $p < .01$. $N = 21$ for all analyses.

Difference scores for FN and P3b amplitudes were computed as the absolute value of gambling-cognitive, with larger scores representing larger negativity for the gambling task than the cognitive task. These difference scores were correlated with the difference scores for the

HRV measures between conditions (Table 6), also computed as gambling-cognitive, with higher scores representing more spectral power in the gambling task. Significant positive relationships were found between LF spectral power difference scores and FN difference scores at FZ, $r = .474$, $p = .030$, and CZ, $r = .438$, $p = .047$. No significant relationships were found for any ERP measure and HF spectral power or LF/HF ratios, or between P3b amplitudes and any HRV measure.

Table 6

Pearson Product Moment Correlations between ERP amplitude difference scores and HRV spectral power difference scores between tasks

ERP	LF	HF	LF/HF Ratio
FN FZ	.474*	.069	.008
FN CZ	.438*	.023	.007
FN PZ	.386	-.034	.000
P3b FZ	-.256	-.145	.086
P3b CZ	-.322	-.177	.312
P3b PZ	-.275	-.186	.226

Note. *= $p < .05$, **= $p < .01$. $N = 21$ for all analyses.

Due to the significant gender differences identified for both encephalographic and heart rate variability measures reported earlier, results were split by gender and correlational analyses between measures were completed (Table 7). Results indicate no significant relationships between any ERP and HRV measure for men. However, significant relationships were found for the female participants between LF spectral power and FN difference scores for all three tested electrodes, including FZ, $r = .676$, $p = .016$, CZ, $r = .684$, $p = .014$, and PZ, $r = .632$, $p = .027$. Similar to the combined analyses above, no significant relationships were found for HF spectral power, LF/HF Ratios, or P3b amplitudes. However, due to the low overall sample sizes in the groups after splitting the data by gender ($n = 9$ for men, $n = 12$ for women), these analyses suffered from low power and negative findings were not interpreted to reduce the likelihood of Type II error.

Table 7

Pearson Product Moment Correlations between ERP amplitude difference scores and HRV spectral power difference scores between tasks split by gender

Men

ERP	LF	HF	LF/HF Ratio
FN FZ	.337	-.046	-.495
FN CZ	.232	-.165	-.531
FN PZ	.187	-.164	-.522
P3b FZ	-.137	-.403	-.194
P3b CZ	-.415	-.253	.591
P3b PZ	-.295	-.336	.279

Women

ERP	LF	HF	LF/HF Ratio
FN FZ	.676*	.124	.439
FN CZ	.684*	.171	.522
FN PZ	.632*	.082	.546
P3b FZ	-.321	-.068	.225
P3b CZ	-.247	-.237	.146
P3b PZ	-.243	-.173	.172

Note. *= $p < .05$, **= $p < .01$. $N = 9$ for Men, $N = 12$ for Women.

Discussion

Win and loss feedback from both tasks were able to elicit a significant FN response, spatially distributed on fronto-central electrodes, with source localization models suggesting a neural generator in the anterior cingulate cortex (ACC). Each task also elicited a significant positive deflection in the waveform suggestive of a P3b component, spatially distributed on posterior-central electrodes, with source localization models suggesting a neural generator near the posterior cingulate cortex or ventral portions of the parietal lobe. Findings supported main hypotheses that there were significantly different FN responses between gambling and cognitive tasks, with gambling tasks showing significantly more negative responses, even with nearly identical visual stimuli.

With the current design, there are three possibilities regarding differences in the tasks. The first is that the tasks provided two different reinforcers: direct monetary reinforcement in the gambling task and points (only possible monetary reinforcement) in the cognitive task. Thus, FN differences between the tasks could represent different participant perception of reinforcement (and loss) value between tasks. The significantly more negative FN responses in the gambling task could be due to losing (or winning) something of more perceived value. The second possibility concerns differences in the number of losses between each task, with the gambling task at a random (50%) win/loss ratio, and the cognitive task reinforcement occurring closer to 75% wins for good performing participants. The final possibility is that the tasks themselves are inherently perceived as different, due to varying perceptions of gambling and cognitive tasks, and differentially engaged executive circuits related to cognitive versus emotion regulation.

One indication of which of these possibilities could be responsible for the FN difference findings comes from the P3b. One model of the P3b, the context updating model, suggests that the P3b represents an update to working memory due to violations of expectations about the environment (Donchin, 1981). In this model, it would be expected that the increased novelty of losses in the cognitive task would lead to differences in the P3b, due to the increased expectation of wins in the cognitive task. However, there were no significant P3b amplitude differences between tasks, which suggest that the somewhat different reinforcement schedules between the two tasks did not have a large impact. While not conclusive, this does provide some evidence that the FN difference findings might not be due to the reinforcement schedule differences. With no monetary reinforcement in the cognitive task, it is not possible to determine if inherent perception of reinforcement value is responsible for the FN differences between tasks, and leaves it impossible to determine if differences are due to reinforcement value differences between tasks or due to perceived differences in wins and losses in the tasks themselves.

If the feedback negativity represents error detection, this suggests that the tasks elicited a greater salience of error detection for the gambling task, even though losses occurred more frequently in that task. However, from the conflict monitoring perspective, these findings indicate that participants had greater expectation of wins in the gambling task and thus more negative responses to loss stimuli. As the participants were directly instructed that the correct responses were randomly determined, objective probabilities would suggest that the opposite response would occur between tasks. One explanation for this could be that participants were engaging in fallacious reasoning about likelihood of winning in the gambling task. Although, another explanation is that participants attributed more value to the monetary losses in the gambling task. Thus, participants could have showed greater perception of error or conflict when monetary reinforcement was not provided.

There were, however, significant gender differences in P3b amplitudes identified for the gambling task, with women showing larger P3b amplitudes than men. This is similar to previous research using an oddball task, where women showed larger P3b amplitudes (Conroy & Polich, 2007). However, this gender finding was not replicated in the cognitive task, providing some evidence of inherent task differences between the cognitive and gambling tasks. From the perspective of the context updating model, these P3b gender differences may represent some inherent gender difference in either the updating of expectation violations in working memory. A second possible interpretation of these differences is that there were gender differences in perceived expectation of winning in the gambling task that was not present in the cognitive task.

When looking at the HRV results, there were also significant differences for each task when compared to baseline. For the cognitive task, there were only significant findings for the HF spectral power, thought to represent mostly parasympathetic nervous system activity. For the gambling task, there was significantly higher LF spectral power than baseline measures, suggesting increased sympathetic nervous system responses in the gambling task. When directly compared, the gambling task also showed significantly higher LF spectral power than the cognitive task, suggesting increased sympathetic nervous system response to the gambling task. LF/HF power ratio results also suggest that the gambling task evoked significantly higher relative sympathetic nervous system responses over baseline, and both were significantly higher than the cognitive task. While these findings support the hypotheses that the gambling task evoked more of an affective response than either the cognitive task or baseline measures, the differences may also be interpreted similarly to the FN differences earlier, as either inherent perception of differences between tasks or different perception of reinforcement value of the stimuli could be responsible for these differences. As these recordings represent summed power across a five-minute period, it is not possible to attribute these responses to particular stimuli. The differences in reinforcers between the two tasks may still be responsible for these differences, with the direct monetary reinforcement in the gambling task having more perceived value than the points. Similarly, these differences could represent an inherent perceived difference between the tasks apart from reinforcement value of the stimuli.

No significant order effects were found for any of the behavioral or psychophysiological responses to the tasks. A number of gender differences were found in the current study, with women showing greater P3b responses in the cognitive task alone. Autonomic gender differences included higher overall HF spectral power for women at both baseline and during the gambling task recordings. A number of other studies have found gender differences in HRV measures, showing significantly higher LF power and LF/HF ratio power in men (Narkiewicz et al., 2005; Ng, Callister, Johnson, & Seals, 1993).

There was some identified shared variance between ERP and HRV measures for the cognitive task, with LF spectral power and LF/HF spectral power ratio significantly negatively related to P3b amplitudes, most prominently at posterior-central electrodes. Presuming the P3b amplitudes are indeed related to novelty of losses in the task from the perspective of the context updating model, results suggest that increased sympathetic responsivity to the task was related to less response to novelty. When separated by gender, significant positive relationships were found between higher LF responses to the gambling task and more negative FN for women, but no relationship for men. One explanation is that women had more autonomic responsivity to loss related feedback in the gambling task, or because the FN is a difference score, greater positive responses to wins was related to more autonomic responsivity.

Conclusion and Directions for Future Research

The tasks used in the current study elicited differences in both ERP and HRV measures. These findings generally support the hypotheses that gambling tasks elicit more autonomic nervous system activity and more negative FN amplitudes, than a cognitive learning task framed as a memory task requiring cognitive ability. While the ultimate determination remains open to different interpretations due to the use of different reinforcers during the tasks, findings support that these tasks may be used in follow up research looking at the relationships of individual differences in personality and psychopathology on feedback negativity and autonomic responses to tasks. The possibility that reinforcers used in the task had different subjective value suggests the need for utilizing monetary reinforcers in the cognitive learning task in follow up research.

The current study is limited by the restricted sample utilized. Participants were young adults from a southeastern college and every participant was either a freshman or sophomore in college, with most of the older, more advanced students in our sample being male. This severely limits generalizability of the results. Further research is needed to replicate the gender differences identified in the current study and to investigate possible ethnicity effects by including more ethnic and culturally diverse samples. Future research using a broad community sample would aid in investigating the generalizability of these results.

Due to the lack of direct monetary reinforcement in the cognitive task, it was not possible to determine if FN differences were due to reinforcement value differences between tasks or due to perceived differences in wins and losses in the tasks themselves. Future studies using similar tasks, both utilizing monetary reinforcement could, aid in making this determination, and are investigated in the next study in this series. However, future research is needed to extend this to other types of reinforcers to help in determining if non-monetary reinforcement results in similar FN response differences.

With these results validating the differential engagement of affective responding by task and the data reduction plan for the personality measures identified in the first study of this work (Chapter 1), all planned foundational studies were complete and allowed conducting a larger multivariate study investigating the interrelationships of possible predictor variables on FN and HRV responses to these tasks.

Chapter 4: Cold Executive Functioning and Personality Relationships with Psychophysiology in a Sub-Clinical Population

Literature Review

Executive functions and feedback processing. The current dominant view of the FN reviewed previously, suggests it is a phasic response to dopamine signals from subcortical processes. The results of the previous study suggests that the FN might not operate as a singular, bottom up, subcortical signal to the cingulate, but may operate differently in response to varying task demands, showing heightened responsivity to tasks eliciting affective processing. While the specific factor eliciting these differences could not be specifically determined due to methodological differences between tasks, it does suggest that the participants engaged in some evaluative process regarding the nature of the tasks, which could have influenced the processing of feedback stimuli. The nature of this evaluation suggests that the FN did not simply operate as a subcortical signal of feedback evaluation, but was influenced by some other top-down, cortical process.

To briefly review the introduction of this work, the cascade of control model (Banich, 2009) may hold particular relevance for understanding the differences between participant responses to the tasks in the previous study. This model suggests a link between the planning activities of the dorsolateral PFC with the subsequent engagement of processing biases and selectively attending to task-relevant information. The actual response selection is suggested to occur in the posterior dorsal ACC, with the anterior dorsal ACC evaluating responses (Banich, 2009). The executive functions using more purely cognitive processing, the so called “cold” executive functions, as opposed to those involving reinforcement learning and affective processing, the “hot” executive functions, makes the response selections. Thus, the cold executive functions related to inhibition and planning would be closely related to feedback processing, as planning would directly influence how the cingulate responds to feedback, and presumably, that behavioral samples requiring use of executive controls for enhanced performance (i.e. neuropsychological testing) would also be related to this feedback processing.

However, there have been very few empirical attempts to link neuropsychological test performance with neurophysiological measures of cognitive control and performance monitoring. Studies looking at individuals with schizophrenia have found relationships between ERN amplitudes and neuropsychological tests, specifically with scores from the Trail Making Test Part B and Wisconsin Card Sorting Test (Kim et al., 2006). Ladouceur and colleagues (2010) used a flanker task to investigate links between negative affect, attention, and the ERN and N2 components in adolescents. Using a self-report measure of attention, not neuropsychological testing, they found self-report attentional control and negative affect interaction effects, as adolescents high in both indices showed significantly higher N2 amplitudes and higher, non-significant ERN amplitudes. The authors suggested that this interaction might be an indication of greater performance monitoring sensitivity in those adolescents with high levels of negative affect that tend to direct greater levels of attention on goal-directed behaviors (Ladouceur, Conway, & Davis, 2010).

Clayson and Larson (2011) investigated these relationships in adults with a battery of neuropsychological tests including the Digit Span subtests from the Wechsler Adult Intelligence Scale-III (WAIS-III DS; Wechsler, 1997), the Controlled Oral Word Association Test (COWAT) and category fluency (animals) from Benton and Hamsher (1976), the Rey Auditory-Verbal Learning Test (RAVLT; Rey, 1964), and parts A and B of the Trail Making Test (TMT; Reitan, 1958). In this study, neuropsychological test results were factor analyzed into factors of Memory

(RAVLT), Verbal Fluency (COWAT, category), and Attention/Executive Functioning (WAIS-III DS, TMT). They found that the Attention and Executive Functioning factor was significantly related to ERN amplitudes and a computed difference score between error-correct trials, while the Memory and Verbal Fluency factors and Negative Affect were not. They found that none of the neuropsychological indices were significantly related to the N2 component. In addition, they found that the Attention and Executive Functioning factor and ERN responsivity were related to greater overall behavioral performance on the task (Clayson & Larson, 2011).

In a follow up analysis of the N2 information from the previous study, conflict adaptation was separated into trials in which individuals actually showed behavioral adaptation to flanker incongruent trials versus congruent trials (Clayson & Larson, 2012). In this case, the Attention and Executive Functioning factor was significantly related to both larger incongruent-trial N2 amplitudes and actual behavioral adaptation effects. Interestingly, the Verbal Fluency factor was also related to overall adaptation effects, which became non-significant after the researchers removed repetitive trials, although analysis of only the repetitive trial data showed that conflict adaptation N2 amplitudes were significantly related to the Memory factor. This suggests that individuals with improved performance on neuropsychological tests of attention and executive functioning showed greater recruitment of cognitive resources following conflict. It is unclear exactly how verbal fluency was related, as the measure was only significantly related to N2 on all trials, and not specifically to either response condition.

While no studies have specifically looked at neuropsychological performance in moderating recruitment of cognitive resources following feedback, these previous studies suggest that there is likely a relationship between measures of attention and executive functioning and the FN. The previous studies used factor analyzed data combining measures of working memory/attention (Digit Span) with measures of processing speed, visual scanning, sequencing, and set shifting (TMT). Thus, the overall composite measure was very limited in specificity, including very few measures that required many facets of executive functioning. It may be that different patterns would emerge if investigated separately.

From the perspective of the cascade of control model, shifting attentional sets, and thus mental flexibility in response to perceived errors, should also related to ACC error responses. Tasks involving more engagement of processing speed, working memory, and sustaining attention over other executive functions should, theoretically, not be as closely related as those of planning and inhibition. Thus, it is likely that a measure of attention (Digit Span) would be related to neurophysiological processing, as would a measure including the need for cognitive flexibility (i.e., set shifting; TMT part B), but not as significantly related to simple scanning, sequencing, and processing speed (TMT part A). Although verbal fluency was found to be significantly related in the overall trial data in the previously reviewed study, the significance of that finding is unclear. As verbal fluency is an output function suggestive of cognitive flexibility and speeded responding (Lezak, 2004), it is closely related to executive functioning and it is conceivable that verbal fluency would be related to cognitive control, but it is unlikely that it would be specifically related to any neurophysiological amplitude measures. As feedback processing in a gambling or pattern-learning task is not greatly dependent on speeded processing or language, it is unlikely that verbal fluency would be greatly related to processing indices. As the overall identified goal of the FN is to inhibit ongoing behavior following detection of goal conflict, it is also likely that it will be most related to neuropsychological measures of conflict and inhibition. Together, this suggests that the few studies investigating these hypothetical relationships between executive function measures and cognitive control psychophysiological responses suffered from inadequate measure selection and the need for studies including many other measures of executive functioning. However, investigation of these relationships should not focus solely on cognitive influences. The cognitive control model is a cognitively focused model, and does not fully integrate engagement of emotional processing as another possible attentional set that could engage the more emotionality focused areas of the ACC. Taking either a top-down or bottom-up approach to investigating cognitive control electrophysiological markers would be myopic, and including both factors is warranted.

Affect and feedback processing. Studies linking negative affect and ERN amplitudes in normal populations have found that individuals higher on self-reported negative affect tend to have larger ERN responses to errors, as well as other psychophysiological indices of autonomic arousal (skin conductance, heart rate; Hajcak, McDonald, & Simons, 2004; Luu, Collins, & Tucker, 2000). With regard to FN, studies dichotomizing anxiety and utilizing monetary rewards in gambling tasks have shown groups low in trait anxiety show significantly higher FN response to negative versus positive feedback than high trait anxiety groups, suggesting different cognitive processes between ERN and FN due to the different patterns of ERP responsivity (Gu, Huang, & Luo, 2010). Compton et al. (2010) dichotomized worry and found that those reporting high levels of worry showed larger FN amplitudes following false feedback in a trial and error learning task involving face images, suggesting that participants with a high level of worry have higher reactance to expectancy violations and not error feedback per se. In a recent study in our laboratory (Highsmith et al., in preparation), state and trait anxiety were not found to be significantly related to FN amplitudes or latencies in either low or high expectancy violation conditions in a pattern-learning paradigm when treated as continuous variables in regression models.

These findings suggest some difficulties in measuring anxiety and worry, or in treating the anxiety construct as a dichotomous variable in other than clinical/non-clinical groupings. Anxiety in the context of personality theories has also been related to ERN amplitudes. Behavioral Inhibition Scale (BIS) scores have been correlated with larger ERN amplitudes following errors in a Flanker Task, while Behavioral Activation Scale (BAS) scores were not (Boksem, Tops, Wester, Meijman, & Lorist, 2006). A similar study design utilizing monetary rewards and punishments found significant BIS/BAS reward/punishment interactions, such that BIS/punishment interactions and BAS/reward interactions were reflected in ERN amplitudes (Boksem, Tops, Kostermans, & De Cremer, 2008).

Studies involving feedback processing have also found relationships between RST constructs and the FN component. Go/No-Go learning involving responding to target stimuli, but inhibiting responses to non-target stimuli, have been used to induce FN responses. Amodio et al. (2007) found that higher self-reported BIS was linked with No-Go N2 ERP responses and conflict monitoring. They also found that BAS was uniquely related to greater baseline left frontal cortical asymmetry estimates. De Pascalis, Varriale, and D'Antuono (2010) used a similar Go/No-Go learning task to induce a FN response, and found a relationship between BIS and the FN response. However, the participants received monetary rewards instead of the simple valence level feedback and results identified significant BAS reward responsiveness by FN interaction and BAS reward responsiveness relationship to induced positive affect during the task. Thus, BAS and positive responses to positive feedback influence FN relationships with cognitive control and suggest the need to limit affective responding during reward tasks to isolate cognitive control markers. Researchers using a task designed to limit affective responding while still delivering reward learning, found no relationship between measures of BIS and BAS with FN responses (Highsmith et al., in preparation). There are also differential findings between measures of BIS/BAS and cortical activity patterns (Hewig et al., 2006). These studies suggest that the cognitive-control, reinforcement sensitivity, and cortical asymmetry models of emotion are linked, but possibly only during engagement of certain types of approaches to tasks.

Looking more generally at extraversion as a putative measure of dopaminergic functioning, Smillie, Cooper, and Pickering (2011) found that FN responses during an associative reward learning task were related to measures of extraversion. The researchers found that extraverted participants showed more responsivity to unpredicted reward and non-reward feedback than introverted participants, and found that a dopamine related gene polymorphism (DRD2/ANKK1) was related to this increased sensitivity to reward expectation violations. Smillie, Cooper, Wilt, and Revelle (2012) used a series of five experiments to show that this relationship between dopaminergic/extraversion as a trait and responsivity to rewards is only engaged under specific conditions. They found that this greater affective-reactivity in extraversion was engaged when the task was clearly related to appetitive stimuli and not simply affective in nature. Also, the reactivity was marked by increased activation and alertness and not simply positive affect. The researchers suggested that this reactivity and engagement of increased arousal may facilitate reward seeking behavior in extraverts. While this may be true, it may also suggest that underlying dopaminergic based variability engages use of reward seeking behavior greater than mood regulation behavior, and greater recruitment of attentional resources to regulate that goal-related behavior.

Even in the Ladouceur and colleagues (2010) and Clayson and Larson (2011, 2012) studies investigating the relationships between executive functions and cognitive control, affective factors may have influenced the results through differential negative affect engagement between subjects. This disparity may be due to the differential engagement of attentional set in the two studies, with the adolescent population being more emotionally reactive to errors than the adult population. However, this remains unclear and warrants additional investigation. It may be that negative affect interacts with executive functioning in situations where the participants are focusing on affective regulation over goal attainment, as evidenced by any identified relationships between FN responsivity and HRV oscillations.

These findings, combined with the findings of the second study of this work (Chapter 3) indicating that feedback processing and autonomic responses are engaged differently by different tasks, suggests that neuropsychological and personality/affective measures may be related to outcome variables in different tasks, based on how those tasks engage participant attentional set. A task framed as a cognitive task (such as the pattern learning task), may prompt feedback processing more related to top-down cognitive abilities such as the cold executive functions of inhibition, attention and working memory and planning. Similarly, when a task is perceived as more affectively engaging (i.e. gambling tasks), it may prompt feedback processing that is more influenced by bottom-up processes of personality and affect.

- *Hypothesis 3 – Neuropsychological measures of attention/working memory, inhibition, and set shifting will relate to neurophysiological measures of feedback processing indicative of goal conflicts in tasks eliciting a cognitive attentional set, such as a pattern learning task, but not in tasks suggestive of emotion regulation attentional set, such as a gambling task. Similarly, the personality measures identified in the first study of this work (Chapter 1) will relate to neurophysiological measures of feedback processing in tasks eliciting an emotion regulation attentional set (i.e. gambling), but not tasks eliciting a cognitive attentional set (i.e. pattern learning tasks).*

Procedure

Participant recruitment and screening. In order to determine relationships between executive functioning measures and personality and the outcome variables of FN amplitudes and HRV indices of autonomic reactivity, 64 healthy, adult undergraduate participants were recruited form the psychology department participant pool and provided class credit for participation (35 women, 29 men). Participant ages ranged from 18 to 22 years (*M* = 18.90, *SD* = 1.04 years). Linear multiple regression power analysis was difficult to estimate, as previous studies had not been completed to allow direct estimation of effect sizes. However, a priori sample size estimation for a linear multiple regression model with two predictors, would need a sample size of 55 to detect a moderate effect size (f^2 =.15), α = .05, β = 0.8, as shown in Figure 18.

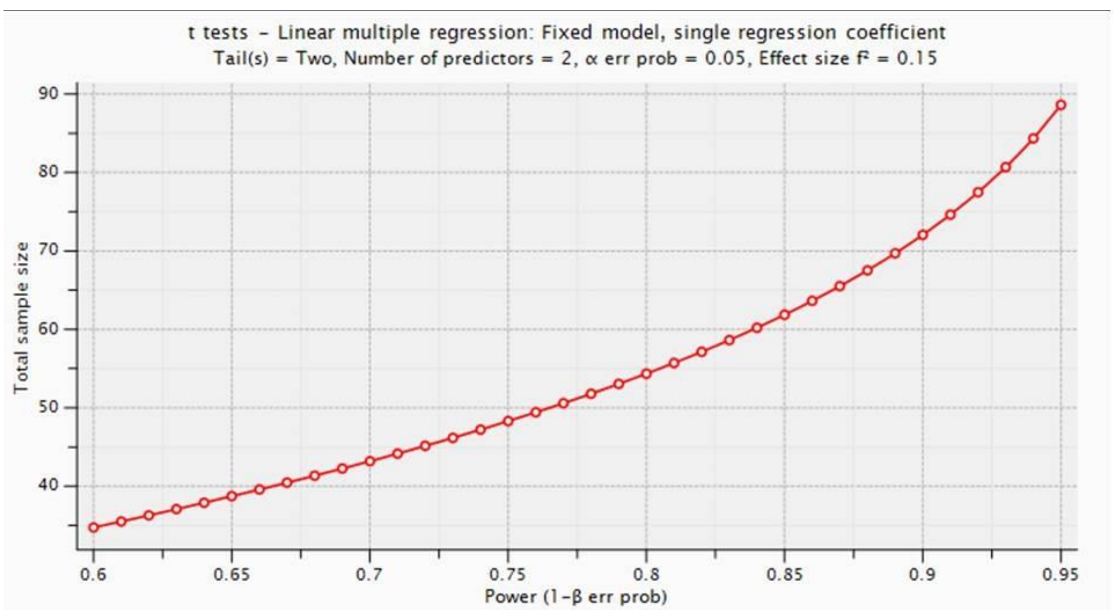

Figure 18 - G*Power A-priori Power Analysis of Linear Multiple Regression

All participants were right-handed and screened for normal or corrected-to-normal vision, no history of neurological disorders, or use of any substances, that might interfere with alertness or electrophysiological measurement. In addition, subjects were rescheduled if they indicated current daytime somnolescence or disturbed sleep the night before reporting for the study. In order to limit any influence of monetary remuneration on participant selection, participants were only informed that they would be receiving both cash rewards based on performance and entry into a raffle for a $50 cash prize after disclosing no disqualifying information. All participants provided written informed consent prior to the start of the study and the study was approved by the University and Medical Center Institutional Review Board (UMCIRB), prior to initiating screening procedures (Appendix A).

Participants completed a number of screening procedures to determine lack of current psychopathology. As the study included gambling behavior, participants completed the South Oaks Gambling Screen (SOGS; Lesieur & Blume, 1987) to screen for possible problem gambling behavior. Similar to results from the previous study, participants reported very little gambling behavior; SOGS scores ranged from 0 to 3 (M = 0.36, SD = .72), with only seven participants (12.5%) reporting any gambling behavior. Of note, male gender was significantly positively related to SOGS scores, r = .267, p = .047, but no participants were excluded for exceeding the standard cutoff of 5 on the measure.

In addition, all participants completed the State-Trait Anxiety Inventory – Form Y (STAI; Spielberger, 1983), with a total mean score at or above 40 on the state measure used to screen for possible clinically significant anxiety symptoms (Knight, Waal-Manning, & Spears, 1983). State scores ranged from 21 to 68 (M = 33.84, SD = 8.46), with nine participants requiring additional screening of reported anxiety symptoms. These nine participants were administered selected modules from the Anxiety-Disorder Interview Schedule for the DSM-IV-TR (ADIS-IV; Brown, Di Nardo, & Barlow, 1994). Participants also completed the Beck Depression Inventory –II (BDI-II; Beck, Steer, & Brown, 1996), with scores at or above 13 used to select participants for additional screenings for symptoms of depression. Participant scores ranged from 0 to 28 (M = 4.57, SD = 3.6), with six participants requiring additional screening and were administered depression modules from the ADIS-IV in addition to the anxiety modules. No participant reported affirmatively to the BDI-II suicidal ideation item (Item #9), precluding the need for initiation of suicide assessment and care procedures or emergency care management.

Of these fifteen participants completing ADIS-IV screening, five met DSM-IV-TR diagnostic criteria for a non-generalized anxiety psychological disorder and were excluded from further participation. These participants received both course credit commensurate with time spent in screening and were offered referral to either the University Center for Counseling and Student Development for available free treatment, or to another local agency if non-university treatment was preferred. Three of the screened participants met DSM-IV-TR diagnostic criteria for generalized anxiety disorder, and were recruited into the fourth study of this work looking at between group investigation of clinical and subclinical levels of anxiety, and were provided similar referrals at the completion of the study. Seven participants did not meet DSM-IV-TR criteria for any psychological disorder and were retained in the current study.

Participant demographics. A total of 56 participants (29 women, 27 men) were retained in the study to complete the experimental procedures, slightly exceeding that needed based on a-priori power analyses (Figure 18). Retained participants were 18 to 22 years of age (M = 19.2, SD = 1.1 years) and reported between 12 and 15 years of education (M = 13.59 years, SD = .76 years), which was significantly positively correlated with age, r = .893, p < .001. No other demographic or screening measure was related to participant demographic variables. However, screening scores for state anxiety (STAI) and depression (BDI-II) were significantly positively correlated, r = .375, p = .004, supporting an underlying link between affective symptomology, even in this psychologically healthy sample. Due to the previous findings of gender differences on FN and HRV outcome variables, one-way ANOVA analyses using gender as the grouping variable were planned for primary outcome measures and are reported below.

Psychological inventories. All participants completed a number of self-report inventories, nearly identical to those measures completed for the first study in this work (Chapter 2). Measures included the trait anxiety measure from the State-Trait Anxiety Inventory – Form Y (STAI; Spielberger, 1983), the Positive and Negative Affective Schedule (PANAS; Watson, Clark, & Tellegen, 1988) presented as a trait measure, Carver and White's (1994) BIS and BAS scales, the Appetitive Motivation Scale (AMS; Jackson & Smillie, 2004), and the Mini-IPIP (International Personality Item Pool; Donnellan, Osald, Baird, & Lucas, 2006). Of note, due to the previous difficulties with the use of idiomatic language for Mini-IPIP item 19 for participants from this convenience sample, the item was changed slightly for the current study, from the original "I seldom feel blue" to "I seldom feel sad."

Neuropsychological assessment. General cognitive functioning was estimated through use of the Test of Premorbid Functioning from the Advanced Clinical Solutions (TOPF; NCS Pearson Corporation, 2009), prior to other testing. All participants were then administered the immediate recall portions of the California Verbal Learning Test – II (CVLT-II; Delis, Kramer, Kaplan, & Ober, 2000) to allow sufficient time for the delayed and recall portions of the test to be given during subsequent neuropsychological assessment. Other tests were presented in a randomized order. Working memory and attention were assessed through use of the Digit Span subtest from the Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV; Wechsler, 2008), and the Ruff 2 & 7 Selective Attention Test (Ruff & Allen, 1996). Participants also completed parts A and B of the Trail Making Test (TMT; Reitan, 1958), the Controlled Oral Word

Association Test (COWAT) and category fluency (animals) from Benton and Hamsher (1976). Participants also completed selected subtests from the Delis-Kaplan Executive Function System (D-KERFS; Delis, Kaplan, & Kramer, 2001) including the Sorting Test, Color-Word Interference Test, and Tower Test, to provide additional assessment of verbal inhibition, planning and reasoning, problem solving, and cognitive flexibility. Specific psychometric properties are presented in Appendix B.

Experimental procedure. Participants were presented a series of three separate tasks using similar stimuli to attempt to differentially engage cognitive and affective attentional sets. As no order effects were found in previous studies in this work, tasks were not cross lagged across participants. Following preparation for psychophysiological recording, participants were seated in a comfortable chair in a dimly lit acoustically shielded room approximately 1m from a LCD stimulus display. Participants were instructed to limit movement and undergo baseline recording procedures. All responses were collected using a four key stimulus keypad, held in both hands, with thumbs used for responses.

Baseline frontal alpha asymmetry. Baseline Frontal Alpha Asymmetry measures were collected using eight one-minute alternating periods of eyes-open and eyes-closed while the participant was presented with a fixation cross. Ocular blink and motor artifact were corrected prior to power spectrum extraction. Each two second epoch was extracted through a Hamming window of 75% overlapping contiguous epochs with spectra calculated using a Fast Fourier Transformation (Allen, Coan, & Nazarian, 2004). Total alpha power was measured between 8 and 13 Hz and assumed to be the inverse of cortical activity (Allen et al., 2004). Total alpha power was tripartitioned into low alpha (8.0–9.5 Hz), mid alpha (9.5–11.5 Hz) and high alpha (11.5–13.0 Hz) bands. Similar to prior data analytic procedures, natural log transformation were used to normalize the spectral data prior to averaging across all baseline measures. Asymmetry scores were computed for each electrode pair as ln(right)-ln(left), with higher scores representing greater disparity toward increased right alpha power and presumably greater left cortical activity (Davidson, 1993).

Pattern task. A pattern learning task was presented using a similar procedure to the cognitive task used in study two of this work (Chapter 3), with the differences consisting of the length of the task. Participants were briefed regarding the experimental procedures and received verbal motivation to maximize winnings, as total points determined raffle entries for the $50 gift card. Correct response choices were not random, and used two card patterns (LL, RR, LR, and RL), that would shift after every four responses. For the current task, participants were instructed to use the thumb of their left hand to select the left card and the thumb of their right hand to select the right card, on the outermost two keys of a four key stimulus keypad. Participants were given the opportunity to conduct two practice series to familiarize them with the game, consisting of two set correct response patterns (LL and RR). There was a slight change to the instructions on the task, when compared to the cognitive task from the previous study, as this task was presented first in the series and was not cross-lagged with the subsequent gambling and hybrid tasks.

Each trial mirrored the experimental procedure from study two, as shown in Figure 19. Readers are directed to Chapter 3 for more specific review of the stimuli procedure. Reinforcement and punishment, defined as feedback that would reduce the likelihood of repeating incorrect responses, remained as points (fixed at 25) and were presented as colored cards filled green for win and red for loss with the number of points won or lost centered in the middle of the rectangle. Response pattern shift was directly signaled between trials. Participants completed fifteen randomly determined patterns across approximately a four minute period. Specific program code utilized is shown in Appendix C.

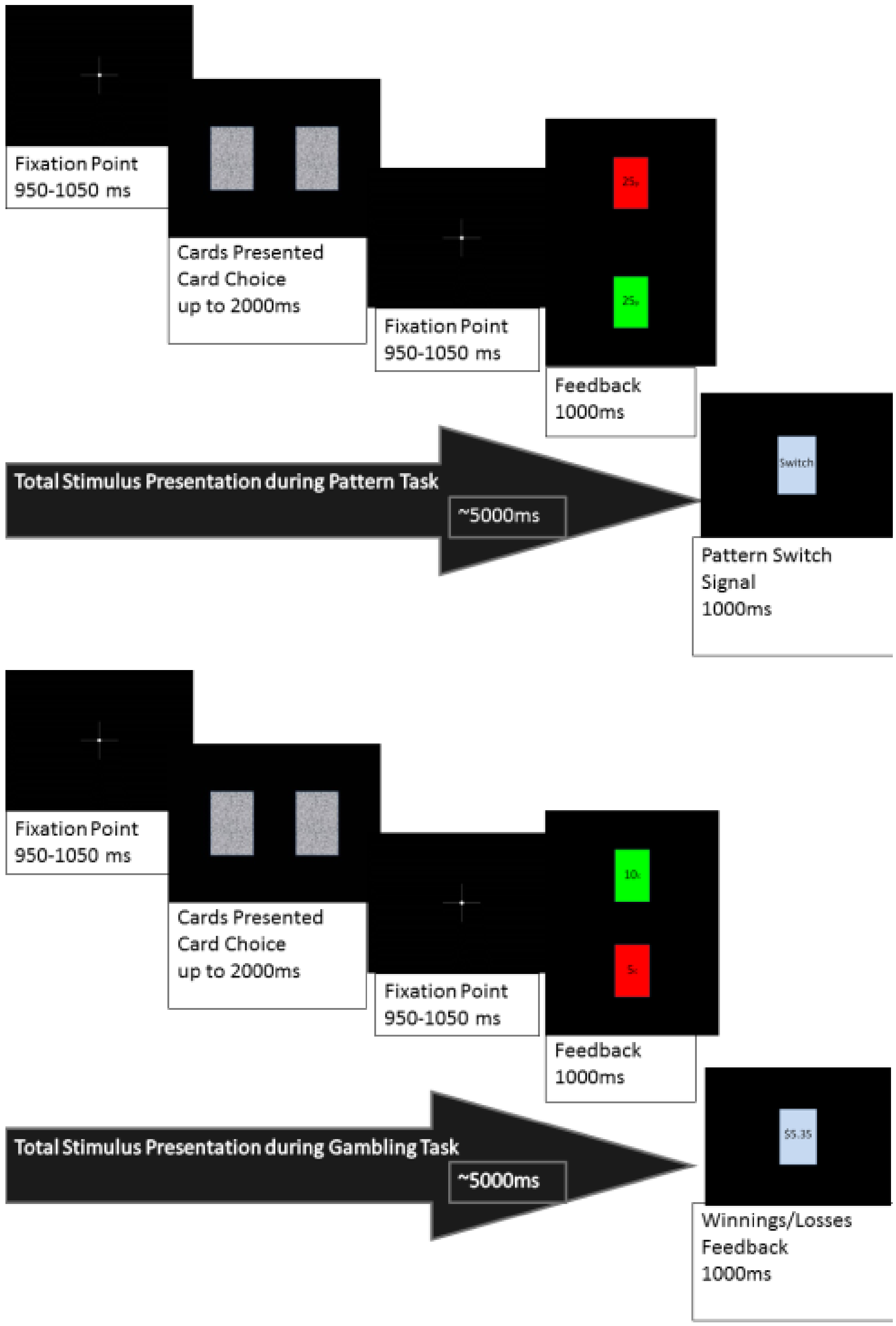

Figure 19 – Pattern and Gambling Task Stimuli

FN measures were computed as differences in averages between the loss and win feedback processing responses across all presented feedback. Correct behavioral adaptation was computed as the total number of behavioral corrections made in response to the negative feedback from the initial two trial phases.

Gambling task. Stimuli and procedures for the gambling task mirrored those from the gambling task from the second study of this work, shown in Figure 19. Reinforcement and punishment consisted of monetary rewards and losses conferred on each trial, again represented with green and red centered rectangles, this time containing the value of the monetary reward (10¢ wins, 5¢ losses). Participants were provided with a one dollar total at the outset of the task, and provided feedback after each four guesses with the total monetary value of their winnings/losses.

Participants were presented with 60 response choices across approximately a three to five minute period. Specific program code is shown in Appendix C. FN measures were computed as differences in averages between the loss and win feedback processing responses across all presented feedback. Total task autonomic response collection over a five minute period was not possible due to the limited time of task. Therefore, a combined period of pattern/gambling autonomic response was computed using LF, HF, and LF/HF ratio power collected between 2.5 minutes of the pattern task and continuing throughout the beginning of the gambling task. As gambling task behavioral adaptation responses are not possible and computed scores were not related to any outcome measure in the previous study, behavioral adaptations were not computed in the current study. Also, deviation from random responding was computed as the inverse of the absolute value of differences between left and right response choices, assuming that random responding should roughly equate to 30 responses per hand, and deviation from this would represent lateral response bias.

Hybrid task. Participants were also presented a hybrid task consisting of a recurring choice to complete the pattern task and gambling task for bonus winnings, with the option to switch games after each four trials (Figure 20). Participants were given instructions explicitly stating that tasks would follow the same procedures as the tasks presented previously, with the exception that the pattern task would provide monetary reinforcement and punishment instead of points. Participants were also instructed regarding the amounts of monetary feedback, with the pattern task providing 5 cent wins and 5 cent losses and the gambling task providing 10 cent wins and 4 cent losses. In order to account for possible laterality preferences, the game choice selections shifted to opposite sides of the screen following completion of each four trail series. While not explicitly stated, this conferred a slight advantage to the gambling task in total magnitude of reinforcement with each four trial series producing an average of 12 cent net gains (2 wins, 2 losses), while the pattern task had an advantage in the frequency of reinforcement while producing an average 10 cent net gains (3 wins, 1 loss). Following each four trial series, participants were presented with winnings and informed that the response pattern for the pattern task was switching. Participants completed a total of 30 series (120 response selections) across an approximate task time of 10 minutes. FN measures were computed as differences in averages between the loss and win feedback processing across all presented feedback and in each response category, pattern and random. Autonomic responses was computed using LF, HF, and LF/HF ratio power collected across a five minute period (2 to 7 minutes) during task commission. Behavioral measures were computed based on the number of selections in each category.

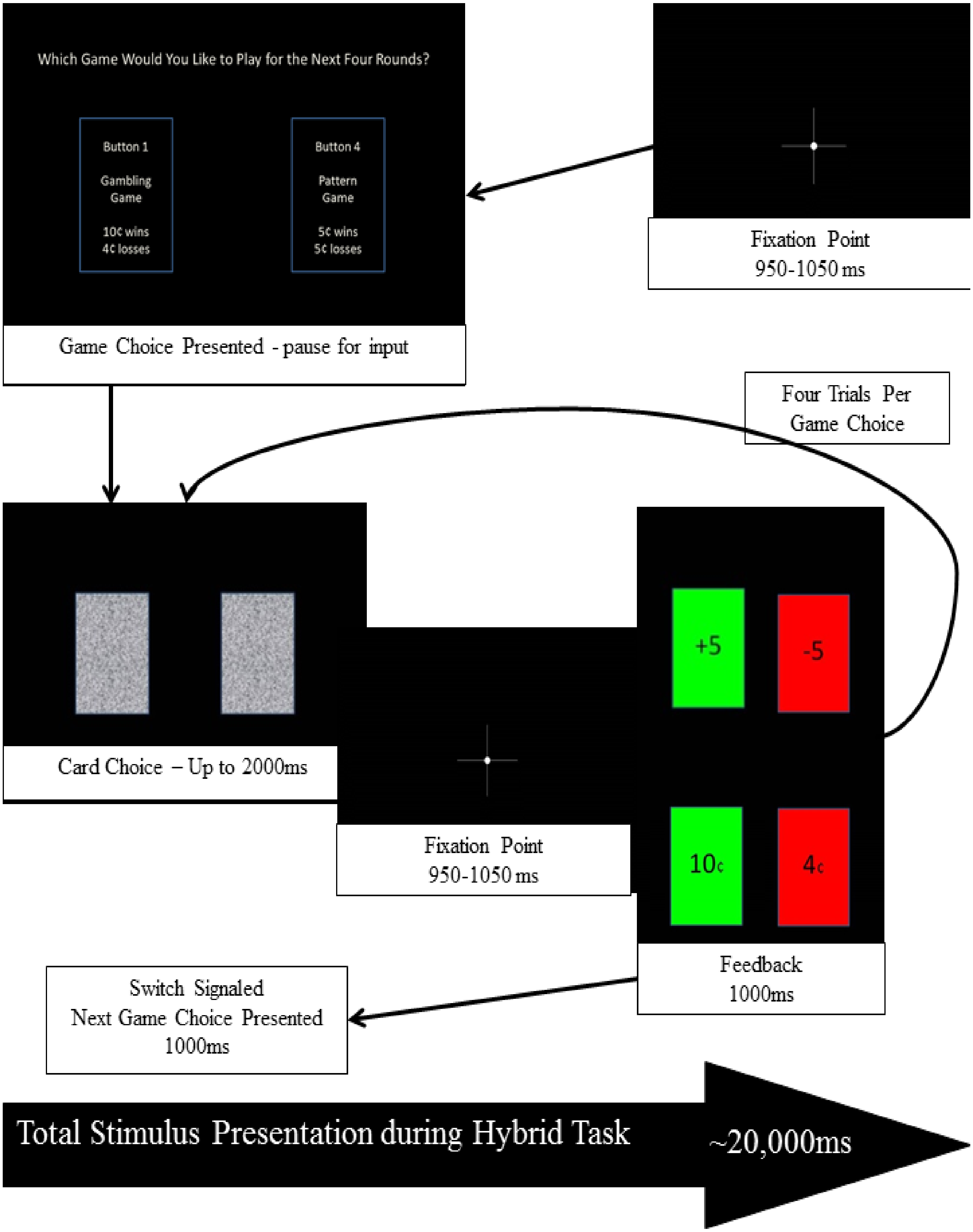

Figure 20 – Hybrid Task Stimulus Presentation

Participants seeking overall magnitude of monetary rewards should show a greater number of selections for the gambling task across trials, while participants seeking overall greater number of wins should show a greater number of selections for the pattern task. A ratio of responses was computed for each participant as gambling selections/pattern selections, with higher scores indicative of seeking monetary rewards magnitude over frequency of positive feedback.

General procedures.

Recording overview. Scalp electrical activity was recorded using Ag/Ag Cl - sintered electrodes mounted in a neoprene Quik-Cap (Compumedics Neuroscan; Herndon, VA) at 30 scalp sites using the international 10/20 placement system (Fp1, Fp2, F7, F8, F3, F4, FT7, FT8, T3, T4, FC3, FC4, C3, C4, CP3, CP4, TP7, TP8, T5, T6, P3, P4, O1, O2, Fz, FCz, Cz, CPz, Pz, Oz). A ground electrode was placed on the frontal midline anterior to electrode Fz, and referenced to linked ears (A1-A2/2). The impedance of all electrodes was maintained at less than 5 kΩ. Eye blinks and Electro-ocular (EOG) activity was acquired continuously and simultaneously using pairs of Ag/Ag Cl – sintered electrodes near the lateral canthus of each eye for EOG measurement, and placed superior and inferior to the midline of the left eye for eye blink measurement. All measurements were acquired using a 40-channel NuAmps DC amplifier and NEUROSCAN ACQUIRE 4.4 (Compumedics Neuroscan), using a 512 Hz sampling rate within the 0.1-100 Hz frequency band, with a notch filter at 50-60Hz. EOG and eye-blink ocular artifact reduction were performed offline using a multiple-lag time domain regression analysis.

Autonomic responsivity. Measures of heart rate variability (HRV) were acquired simultaneously with EEG recording to provide estimates of autonomic nervous system regulatory balance, with 5 minutes of baseline HRV taken at baseline. Following beginning data collection, it was revealed that participants could complete the pattern tasks within five minutes, and although HRV measurement was planned for each task, a measurement was taken from 3 minutes following initiation of the pattern task continuing into the gambling task. A final 5 minute period was collected during performance of the hybrid task, taken between minutes 2 and 7 of task performance. While this set of recordings precluded more detailed investigation of affective responses to tasks, as both task related measures were composed of both pattern and gambling tasks, it did allow investigation of within subject affective responses across the tasks. Electrocardiographic (ECG) measures were collected using three Ag/Ag-Cl -sintered electrodes placed bilaterally on the participants' wrists. All measurements were recorded using a BIOCOM 3000 ECG system and Heart Rhythm Scanning Software (Biocom technologies, Poulsbo, WA). Spectral data were extracted using a Fast Fourier Transformation (FFT) procedure. Frequency band was defined using standard frequency oscillation ranges with Low Frequency (LF) band defined between 0.04 and 0.15 Hz and the High Frequency (HF) band between 0.15 and 0.4 Hz (Task Force, 1996). In addition, LF/HF ratios were calculated for each recording, with higher values representing sympathetic system domination and higher affective responses to tasks.

ERP measures. ERPs were extracted from continuous measurements using 1100ms epoch windows, including a 100ms pre-feedback baseline and the 1000ms following feedback presentation following electro-ocular movement corrections. All files were digitally filtered using a 6 dB band-pass filter (0.1 to 100Hz) and baseline corrected relative to the 100ms pre-feedback baseline. Grand average waveforms were averaged from total loss and total win feedback across all trials and conditions for the FZ, CZ, and PZ electrodes (Figure 21). Overall difference waves (Figure 22) for each electrode revealed a negative deflection in the wave similar to the previous study between 225 and 325 ms, consistent with a FN response.

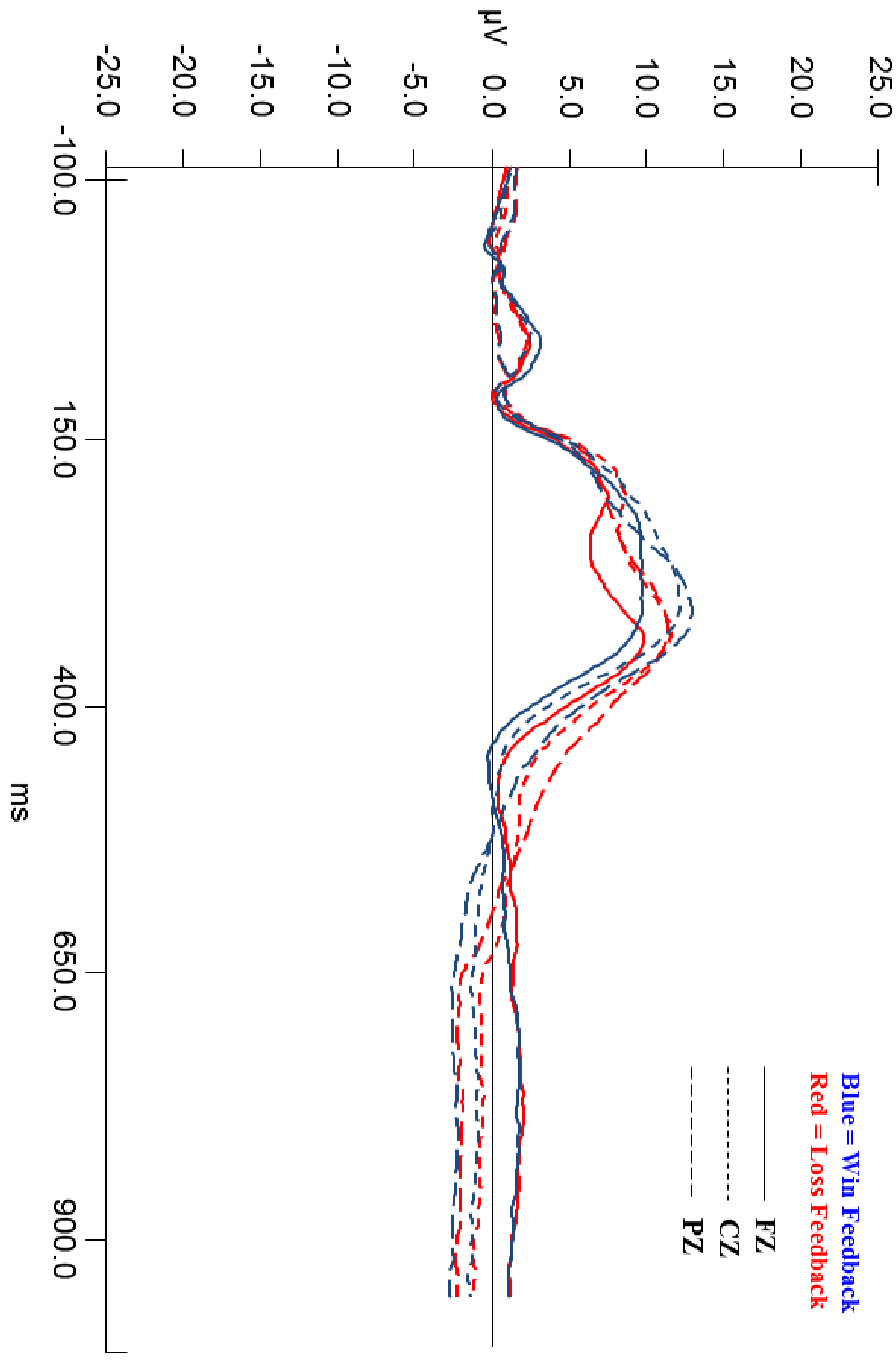

Figure 21 – Grand Average Waveforms

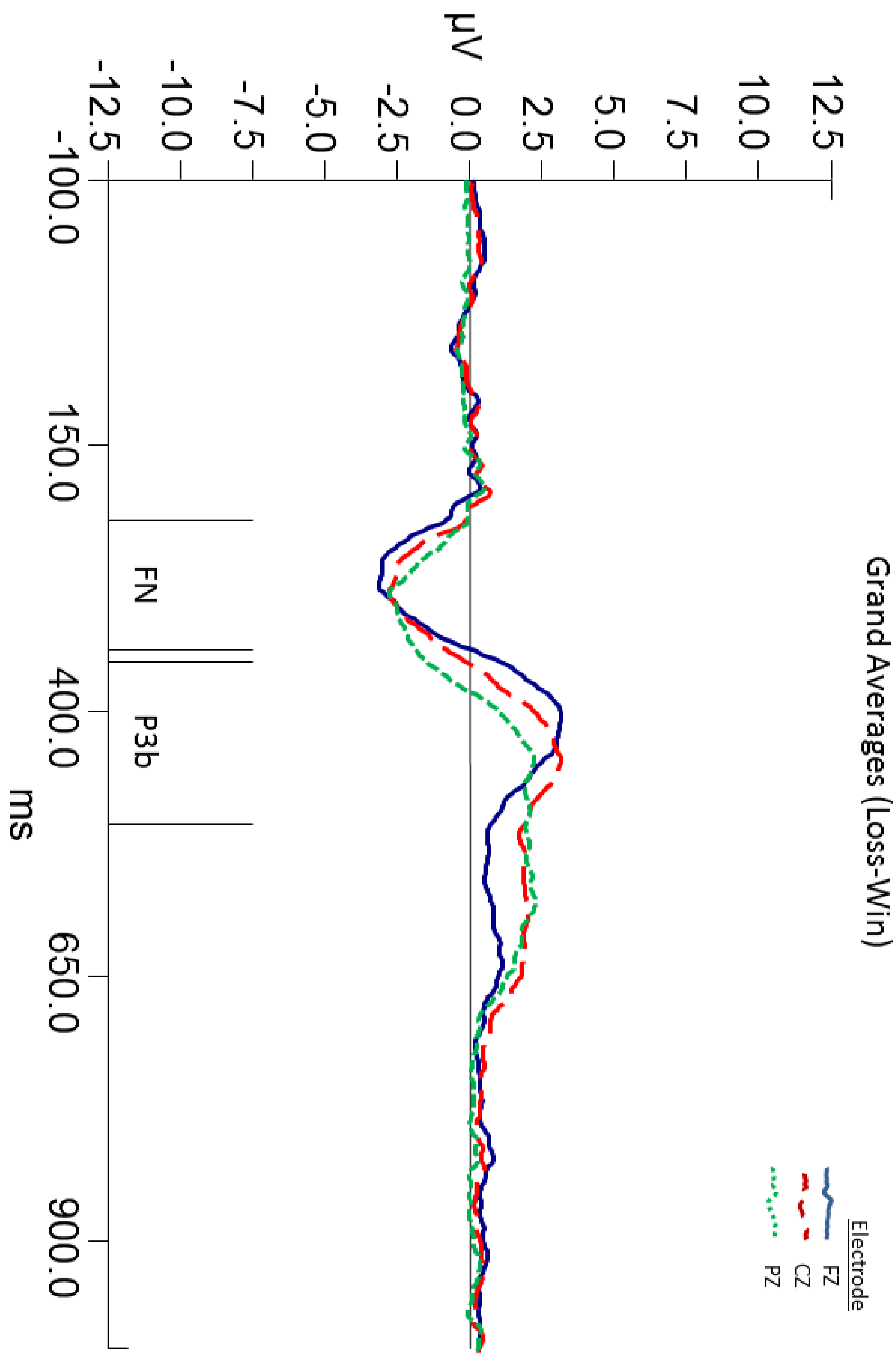

Figure 22 – Grand Average Difference Waveforms

In addition, a significant positive deflection occurred between 350 and 450 ms, consistent with a P3b novelty response (Figure 22). FN amplitudes were extracted as the most negative peak in the 225 and 325 ms time window and computed as a difference score between the loss and win feedback peaks extracted for all midline electrodes for each task condition. P3b amplitudes were similarly extracted as the most positive peak in the time window between 350 and 450 ms and computed as the difference score for all midline electrodes for each task condition.

Results

Data screening. Analysis of missing data proved unnecessary, as all participant self-response results were screened by study personnel and reviewed with the participants for indicators of possible psychopathology, allowing completion of any missing responses prior to initiation of neuropsychological and psychophysiological portions of the study. Outlier analysis was undertaken prior to all major analyses, using Box-and –Whiskers plots. Of note, one participant showed generally significantly higher cognitive and executive functioning scores from other participants, although the participant was no longer a significant outlier after unit-weighted combination of scores from factor analyses reported below. Univariate indices of kurtosis and skewness were examined to determine non-normality and data transformation procedures, with variables transformed if their absolute value was greater than 2.0. Multivariate outlier analyses were pursued using leverage scores calculated for all variables included as predictors, and are reported below.

Behavioral results. Scores from the pattern task ranged from 70 to 330 points (M = 226.43, SD = 68.18). Average response latencies in the pattern task ranged from 542 ms to 2973 ms (M = 1563 ms, SD = 600 ms). A percentage of correct adaptations were computed for each participant and ranged from 20% to 100% (M = 73.7%, SD = 23.7%). The number of adaptations were significantly correlated with overall score on the pattern task (r = .790, p < .001). A one-way ANOVA of cognitive scores between genders was not significant, $F(1, 55) = .232$, $p = .632$, showing no gender differences in pattern scores.

Winnings from the gambling task ranged from -45¢ to $2.30 ($M$ = $0.80, SD = 61¢). Average response latencies in the gambling task ranged from 364 ms to 3914 ms (M = 1360 ms, SD = 821 ms). Similar to the pattern task, a one-way ANOVA of gambling task scores between genders was not significant, $F(1, 55) = 2.587$, $p = .114$, showing no gender differences in gambling scores. The hybrid task allowed participants to choose gambling or pattern task performance and a percentage of pattern choices were computed for each participant, ranging from 0% (all gambling) to 100% (all pattern). Overall mean of choices was 55% pattern (SD = 30%). A one-way ANOVA of pattern choices between genders was not significant, $F(1, 55) = 0.436$, $p = .512$, showing no gender differences in game choices.

Affective response to task. Although the current study was initially designed to allow specific relationships between heart rate variability responses to tasks and personality and neurocognitive measures, the total time across initial tasks did not permit separate five minute HRV recordings. Thus, differentiation of HRV responses to pattern or gambling tasks was not possible. However, three separate measures of HRV responses to task were taken (Baseline, Pattern/Gambling, and Hybrid tasks), allowing investigation of overall affective responses to the tasks through repeated measures ANOVA of LF/HF ratios. A significant within-subject linear increase in LF/HF ratios was found across the task $F(2, 53) = 8.427$, $p = .005$, $\eta 2 = .133$. As shown in Table 8, the overall ratio for the baseline period was 0.968, suggesting greater HF modulation and presumably greater parasympathetic activity during this period, which increased to greater relative LF modulation during the games. Pairwise comparisons using Fisher's procedure indicated that the mean ratio was significantly less for the baseline period, but that ratios during the two game periods did not significantly differ.

Table 8. Mean LF/HF Ratios.

Period	LF/HF Ratio
Baseline	0.968^{A}
Pattern/Gambling	1.063^{B}
Hybrid	1.084^{B}

Note: Means with the same letter in their superscript are not significantly different from one another.

Neuropsychological assessment analysis.

General functioning. General cognitive functioning estimates from the Test of Premorbid Functioning from the Advanced Clinical Solutions (TOPF; NCS Pearson Corporation, 2009) ranged from 84 to 133 (SS; Standard Scores). As no participant scored less than 1.5 *SD* below the mean of the normative populations, no participants were removed from the analysis for possible impairment in premorbid cognitive ability. Standard Score mean performance (105, *SD* = 13.31) was slightly higher than the normative sample on the measure, as was expected of a college sample.

Component analysis. As all neuropsychological instruments utilized in the current study are widely used and accepted measures in clinical practice, specific item analyses were not undertaken. All participant results were scored relative to age norms and education norms where possible, and resultant scores were transformed into z-scores representing participant deviation from normative sample means in units of published measure population standard deviations. Overall means and standard deviations from neuropsychological test scores are presented in Table 9 below.

Table 9

Neuropsychological test z-scores in an undergraduate sample (N = 56)

Test	Mean	*SD*	Std. Error
WAIS-IV Digit Span	0.576z	1.165z	0.156
Ruff 2&7 Overall Dif	0.229z	1.272z	0.170
CVLT-II Imm Free Recall	0.595z	0.914z	0.122
CVLT-II *SD* Free Recall	0.54z	0.776z	0.104
CVLT-II LD Free Recall	0.29z	0.756z	0.101
COWAT	0.196z	1.202z	0.161
Animal Fluency	0.282z	1.042z	0.139
CWIT Color	0.048z	0.886z	0.118
CWIT Word	0.161z	1.031z	0.138
CWIT Inhibit	0.196z	0.949z	0.127
CWIT Inhibit/Switching	-0.220z	1.079z	0.144
D-KEFS Sorting Correct	0.208z	0.823z	0.110
D-KEFS Sorting Description	0.071z	0.914z	0.122
D-KEFS Tower Achieve	0.660z	1.066z	0.142
D-KEFS Tower Total Moves	0.652z	1.072z	0.143
TMT-A	0.200z	0.689z	0.092
TMT-B	-0.067z	0.913z	0.122

Of note, most participant performances were higher than the overall normative sample, particularly on items involving auditory working memory (WAIS-IV Digits Span) and auditory immediate and delayed recall (CVLT-II) as well as planning (D-KEFS Tower), perhaps due to a selection effect for mental abilities associated with increased school performance and decision making regarding entering college. Participants were closer to overall normative sample performances on tasks involving speeded responding such as verbal fluency tasks and rapid reading/inhibition. Of note, participant mean scores were lower than the overall normative sample on a task requiring speeded responding in the context of a task involving set shifting between reading and inhibiting reading responses (CWIT inhibition/switching) and on a task requiring set shifting between speeded visuospatial number and letter sequencing (TMT-B).

While the reason for this reduced performance relative to the normative samples remains unknown, additional analyses of errors on CWIT tasks revealed reduced total errors on the switching task (*M* = -0.166z, *SD* = 0.945z), perhaps representing a general tendency for the sample to focus on accuracy in the task over speed.

Initial review of component analysis anti-image correlation matrix revealed that animal fluency z-scores were significantly below the recommended Kaiser-Meyer-Olkin measure of sampling adequacy (MSA) value of .5, specifically at 0.439. This is perhaps due to significant shared variance with phonetic fluency (COWAT), $r = .422$, $p < .001$, that was not shared with other measures. Therefore, animal fluency was removed for subsequent analyses.

The remaining computed z-scores entered into subsequent analysis were taken from the Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001) Sorting Test (Sorts and Descriptions), Tower test (Total Achievement Score and Total moves), and Color-Word Interference Test (total time score from each four conditions), as well as from the California Verbal Learning Test – II (CVLT-II; Delis, Kramer, Kaplan, & Ober, 2000) immediate recall, short delayed free recall, and long delayed free recall, Digit Span subtest from the Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV; Wechsler, 2008), overall difference scores from the Ruff 2 & 7 Selective Attention Test (Ruff & Allen, 1996), parts A and B of the Trail Making Test (TMT; Reitan, 1958), and the Controlled Oral Word Association Test (COWAT). These remaining 16 scores were entered into a principal components analysis. Initial analysis indicated that scores were adequate for principal components analysis. Specifically, the overall Kaiser-Meyer-Olkin measure of sampling adequacy (MSA) was .722, above the recommended value of .6, indicating the resultant factors would account for a good amount of variance among the entered scores. In addition, Bartlett's test of sphericity was significant, χ^2

(120) = 741.43, $p < .001$, suggesting these scores do not come from a population in which the intercorrelation matrix is an identity matrix and appropriate for analysis. Inspecting each item from the diagonals of the anti-image correlation matrix revealed that the MSA for every item was above .628, with the exception of TMT-B (.556), which was retained in the analysis.

Review of initial Eigenvalues identified four components with initial Eigenvalues greater than 1.0 (lowest of these 1.522), the first explaining 30% of the variance, the second explaining 18%, the third explaining 14%, and the fourth explaining 10% (71.49 cumulative %) with 12 components with initial Eigenvalue lower than 1. Review of the scree plot suggested a four factor solution. This was supported by a parallel analysis which also indicated a four factor solution. However, both an original and a revised MAP tests suggested a three factor solution. Four factors were retained explaining approximately 71% of the variance among the items, and were rotated using a varimax procedure.

The first component consisted of scores from the D-KEFS Tower test and Sorting Test. As this component was composed of tasks requiring planning and higher order categorization of stimuli, this component was termed Executive, due to the heavy focus on higher order executive functioning required for high scores. The second component was composed of scores from the CVLT-II and WAIS-IV Digit Span scores. As this composed of tasks requiring memory functioning (and auditory attention), this component was named Memory. The third component consisted of the four scores from the D-KEFS Color Word Inhibition Test, representing overall speed of identification of colors, reading color words, and performing more difficult tasks of inhibiting natural reading responses and switching between natural and inhibition response rules. As the task involves a high level of inhibition, the component was named Inhibit. Finally, the fourth component consisted of scores from the COWAT requiring speeded verbal responding, the TMT requiring speeded visual scanning, sequencing, set shifting, and organizing speeded motor responses, and scores from the Ruff 2 & 7 Selective Attention Test requiring speeded identification and selection of target stimuli from foils. As each of these tasks is heavily dependent on speeded responding, this component was named Speed. It is acknowledged that many of these tests require functioning in multiple cognitive domains, and these components do not equate directly to a combined measure of any particular cognitive domain. However, selected names were chosen to represent the cognitive exemplar of their respective tests. The loadings from the final factor solution are shown in Table 10 and graphically in Figure 23.

Table 10

Principal components analysis with varimax rotation factor loadings for neuropsychological z-scores in an undergraduate sample (N = 56)

Measures	Executive	Memory	Inhibit	Speed
D-KEFS Tower Achieve	.895*	.015	.127	.128
D-KEFS Tower Total Moves	.896*	.026	.118	.140
D-KEFS Sorting Correct	.892*	.053	-.045	.120
D-KEFS Sorting Description	.867*	.020	.037	.164
CVLT-II Imm Free Recall	.051	.847*	.123	.081
CVLT-II *SD* Free Recall	-.055	.880*	.047	.045
CVLT-II LD Free Recall	.051	.868*	.203	.045
WAIS-IV Digit Span	.090	.579*	.032	.516
CWIT Color	.065	.130	.876*	.093
CWIT Word	.119	.290	.798*	-.145
CWIT Inhibit	.133	.041	.865*	.085
CWIT Inhibit/Switching	-.079	.000	.875*	.243
Ruff 2&7 Overall	.274	.339	.026	.521
COWAT	.165	.110	.004	.793
TMT-A	.303	.092	.140	.588
TMT-B	-.039	-.097	.108	.678

* - measures utilized in combined score loadings

Of note, a number of tests loaded heavily on more than one of the components. One example of this is the WAIS-IV Digit Span subtest which loaded heavily on Memory (r = .579) and on Speed (r = .516). This test requires auditory attention and working memory to remember and repeat a string of digits forward, backward, and in sequential numerical order. While this task does not require significant levels of speeded responding, it is heavily dependent on auditory attention. Of the tests loading onto the Speed component, the Ruff 2 & 7 task also requires sustained attention and loaded onto that component only slightly better than did digit span scores (r = .521). This suggested that the fourth component actually represented attention and processing speed, which are required underlying abilities for nearly all tests of neurocognitive functioning. As this fourth component did not represent any single theoretically unified aspect of cognitive functioning, it was removed from later analyses, and the first three factors were retained as suggested by MAP analyses.

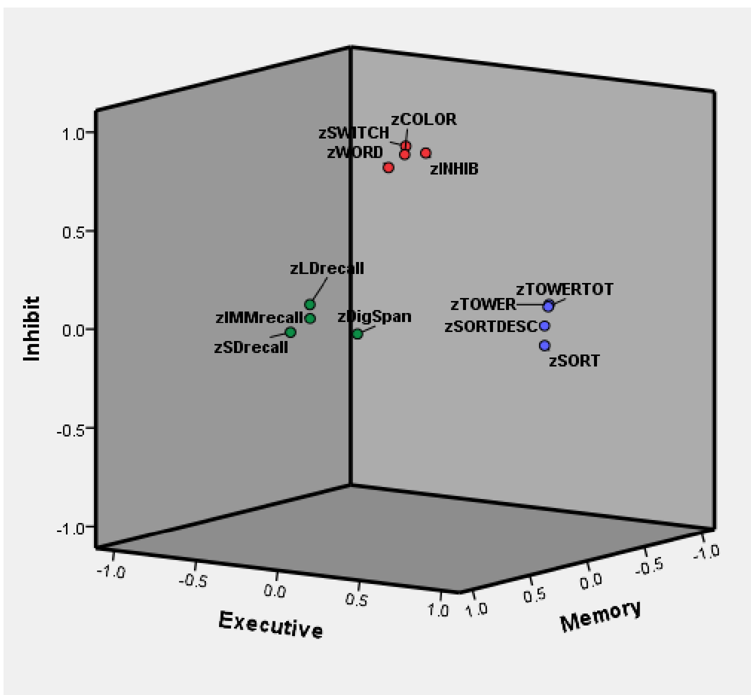

Figure 23 – Component Loading Plot of Neuropsychological z-scores

Unit-weighted component scores were computed for each participant for these three components representing the combination of the actual z-scores from measures loading at least a third as large as the largest overall loading for each variable in the component (Grice, 2001).

Utilized scores are represented above in Table 9, identified for each component with an asterisk. Unit-weighted scores were utilized as these z-scores have inherent interpretive meaning and will allow computed component scores to represent total participant variability. In addition unit-weighting scoring systems have been shown to be preferable in situations of complex structure, using score coefficients to determine loadings (Grice, 2001; Grice & Harris, 1998).

Statistical hypotheses and tests. Component scores were found to be positively correlated between all measures, indicating that participants who scored highly on any of the components tended to score highly across other components. However, this relationship was only found to be significantly positively correlated for Inhibit and Memory, $r = .259$, $p = .047$, while non-significant for Executive and Memory, $r = .131$, $p = .323$, and for Executive and Inhibit, $r = .148$, $p = .265$. Scores on each were not found to be significantly related to the demographic variables of age, education, or gender.

It was expected that these computed component scores would significantly correlate with mood, FN responsivity, and behavioral adaptation in the experimental tasks. It was also expected that depression scores on the BDI-II would significantly correlate with executive functioning measures, however, BDI-II scores did not significantly relate to any of the component scores including Memory, $r = .082$, $p = .547$, Inhibit, $r = .210$, $p = .120$, or Executive, $r = .119$, $p = .380$. Similar to previous findings in our laboratory (Highsmith et al., in preparation), it was expected that trait anxiety scores would significantly correlate with measures of vigilance and inhibition. STAI-T scores were found to be significantly related to overall Inhibit scores, $r = .281$, $p = .036$. It was also expected that scores on executive functions (Executive) and inhibition (Inhibit) would significantly correlate with FN responsivity to errors. However, no significant relationships were found between these component scores and FN amplitudes.

Similarly, no significant relationships were found when applied to behavioral scores, including overall scores and adaptation to losses, or on decisions to participate in more pattern trials versus gambling trials in the hybrid task.

Personality variable hypotheses and tests. Due to the difficulties noted previously with loadings from the BAS scales from the personality components identified in the first study of this work, a separate principle components analysis was conducted on personality variables in the current sample. As each of these scales have separate scoring procedures and disparate score ranges, individual participant scores were standardized into z-scores relative to normative means and standard deviations of the measures. Initial analysis indicated that scores were adequate for principal components analysis. Specifically, the overall Kaiser-Meyer-Olkin measure of sampling adequacy (MSA) was .635, above the recommended value of .6, indicating the resultant factors would account for an adequate amount of variance among the entered scores. In addition, Bartlett's test of sphericity was significant, χ^2 (55) = 197.05, $p < .001$, suggesting these scores do not come from a population in which the intercorrelation matrix is an identity matrix and appropriate for analysis. Inspecting the MSA for each item from the diagonals of the anti-image correlation matrix revealed that the MSA for every item was above .5, and were retained in the analysis.

Review of initial Eigenvalues identified four components with initial Eigenvalues greater than 1.0. Review of the scree plot suggested a three component solution. This was supported by a parallel analysis which also indicated a three component solution. However, both an original and a revised MAP tests suggested a two component solution. As the three factor solution was found similar to the factors identified in the first study of this work (Chapter 2), the three component solution was utilized in subsequent analyses, the first explaining 38% of the variance, the second explaining 17%, and the third explaining 12% (58% cumulative). Overall loadings are presented below in Table 11.

Table 11

*Principal components analysis with varimax rotation factor loadings for personality and appetitive motivation measures in an undergraduate sample (*N *= 56)*

Measure	Maintenance	Suppression	Seeking
BAS-RR	.790*	.010	.152
C	.773*	-.035	-.056
BAS-D	.689	-.129	.280
PA	.670*	-.240	.014
A	.345	-.102	.161
STAI-T	-.189	.851*	.023
N	-.064	.828*	-.023
NA	-.198	.681*	.095
BIS	.042	.670*	-.437
BAS-FS	.135	.121	.823*
AMS	.384	.104	.682*
E	.028	-.233	.681*

* - Retained in unit-weighted computed scores

In the current sample, most loadings were in the specific direction. Of note, in the current sample, agreeableness did not load highly onto any factor (although it loaded significantly onto Maintenance in the original sample). Also of note, the drive component of the Behavior Activation Scales (BAS) loaded onto the Maintenance component in the current sample, while it loaded onto the Seeking component in the original sample. These results suggest some difficulty with including both agreeableness and BAS-D in the measures of the theorized three components, and both were removed from computation of component scores. A variable named Suppression was computed and was composed of trait anxiety (STAI-T), neuroticism (N), negative affect (PANAS-NA), and behavioral inhibition (BIS) scores. Also, combined scores were computed for a variable named Seeking composed of the fun seeking portion of BAS (BAS-FS), appetitive motivation (AMS), and extraversion (E) scores. Finally, scores were computed for a third component variable named Maintenance consisting of the reward responsiveness portion of BAS (BAS-RR), conscientiousness (C), and positive affect (PANAS-PA) scores. Unit-weighted loadings were computed in accordance with procedures identified by Grice (2001). These scores were computed based on a linear combination of overall scores on each measure. Unlike neuropsychological test data, computation of z-scores was not undertaken for these personality data. Thus, component scores represent simply a combination of scores on the individual measures.

Table 12

Retained personality components relationships with demographic and psychiatric screening measures in an undergraduate sample (N = 56)

Measure	Maintenance	Suppression	Seeking
Age	-.036	.152	.152
Gender	.019	-.338*	-.056
Education	-.001	.084	.280
SOGS	.017	-.116	.014
BDI-II	-.181	.458**	.161
Memory	.210	.006	.033
Executive	-.064	.028	-.061
Inhibit	-.194	.228	-.039

* = p < .05, ** = p< .001

As shown in Table 12 above, none of the personality components were significantly related to age or education of the participants. In addition, none of the scores on these personality and appetitive motivation components were significantly directly related to retained components from neuropsychological PCA analysis (Executive, Memory, and Inhibition). However, the Suppression component was significantly negatively related to self-identified participant gender, with higher Suppression scores related to identification as female, $r = -0.338$, $p = .011$. Also shown in Table 12 are the relationships between these personality components and scores on screening measures, with high scores on Suppression being significantly related to higher scores of depressive symptomology on the BDI-II, $r = .458$, $p < .001$. Similar to previous studies in our laboratory (Highsmith et al., in preparation), higher scores related to problematic gambling symptomology (SOGS) were significantly related to gender, with higher scores associated with male gender, $r = .267$, $p = .047$. Due to these gender differences, and findings of gender differences on primary outcome measures during the second study of this work (Chapter 3), primary outcome relationships were separately conducted for each gender.

Electroencephalographic results. While direct between task comparisons were not initially planned, as these comparisons were the basis of the previous study of this work, inclusion of the monetary reinforcement in the pattern task portion of the hybrid task allowed the investigation of one of the lingering questions from the previous study regarding possible FN differences resulting from inherent differences in the perception of reinforcers. Paired sample *t* tests were conducted on FN amplitude measures for both of the pattern tasks, representing differences in feedback processing for reinforcement with 5 points and 5 cents. Tests revealed significant differences for the FZ electrode (Figure 24), $t(55) = 2.450$, $p = .017$, $d = 0.36$. This mean difference was only 1.5 µV and a small to medium effect. No differences were found for electrodes CZ (Figure 25), $t(55) = 1.538$, $p = .130$, $d = 0.24$, and PZ (Figure 26), $t(55) = 1.11$, $p = .271$, $d = 0.17$.

These results suggest that there were some significant differences between feedback processing for monetary and point based reinforcement. These data suggest that perceptions of reinforcer value may have contributed to the between task differences in the previous study of this work. However, those identified magnitudes of effect were very large for between task differences, with an effect size for the FZ electrode at 1.27 (Chapter 3), suggesting that reinforcer difference may have contributed to but likely cannot account for these between task differences.

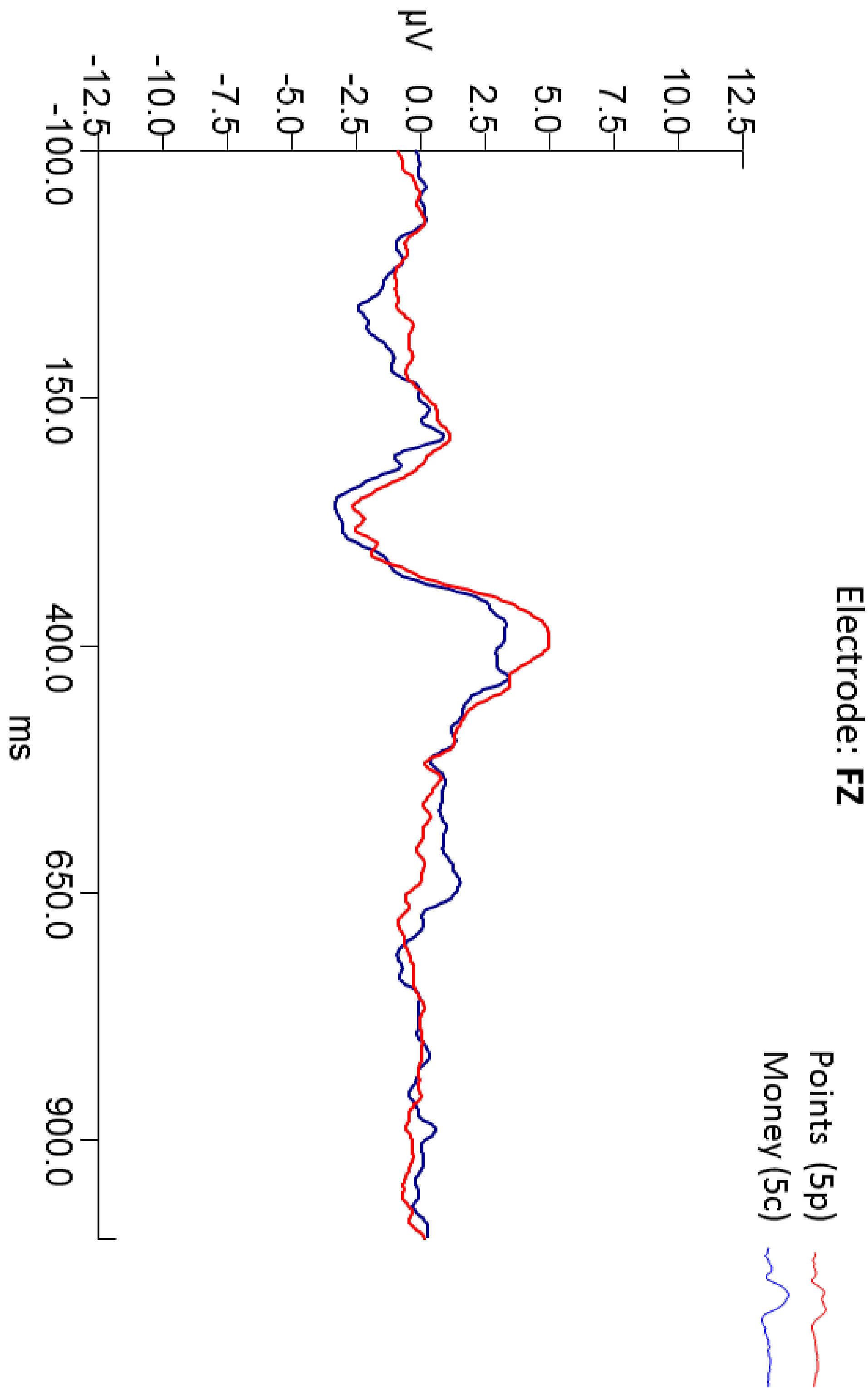

Figure 24 – Pattern Task Waveforms FZ Electrode

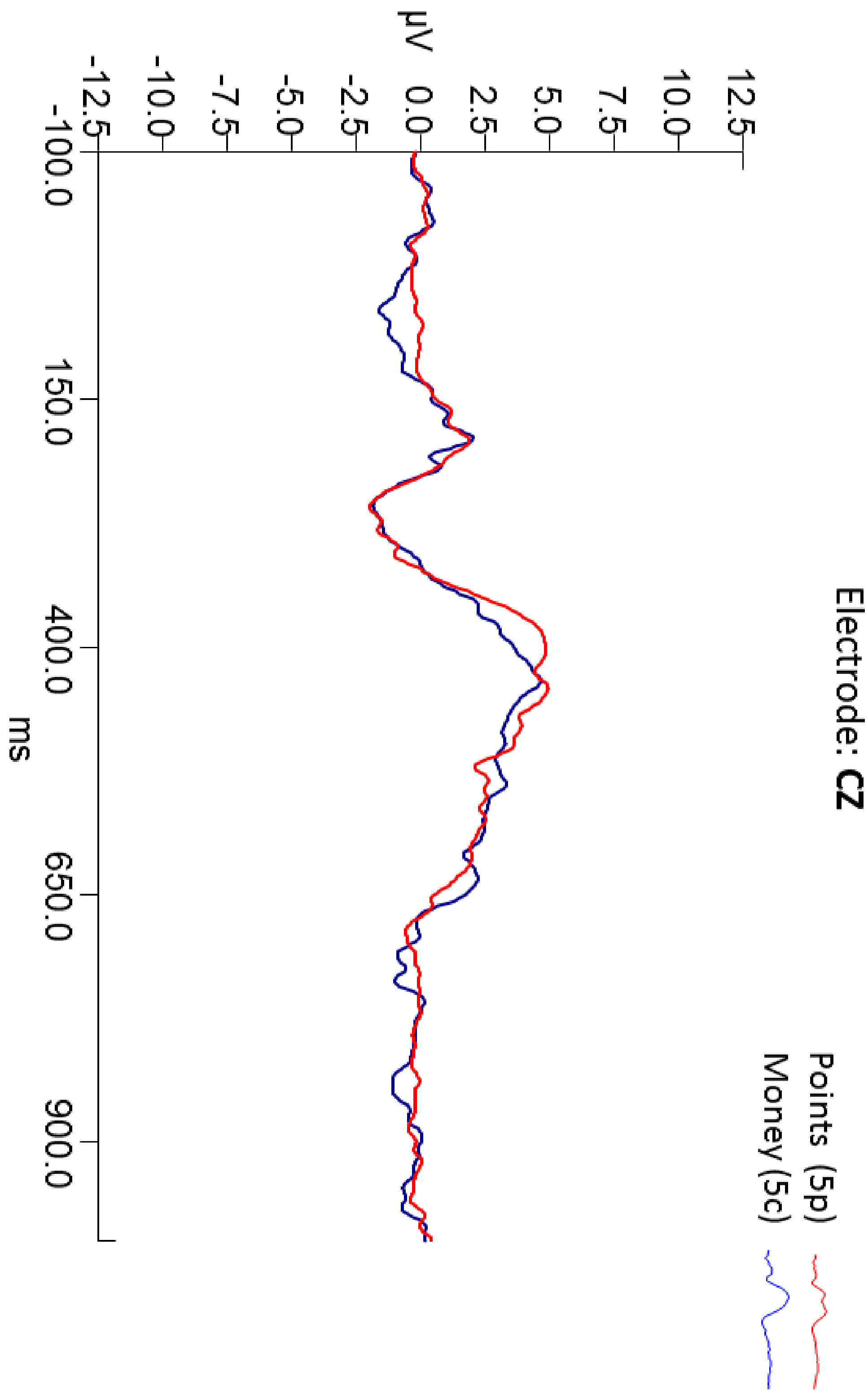

Figure 25 – Pattern Task Waveforms CZ Electrode

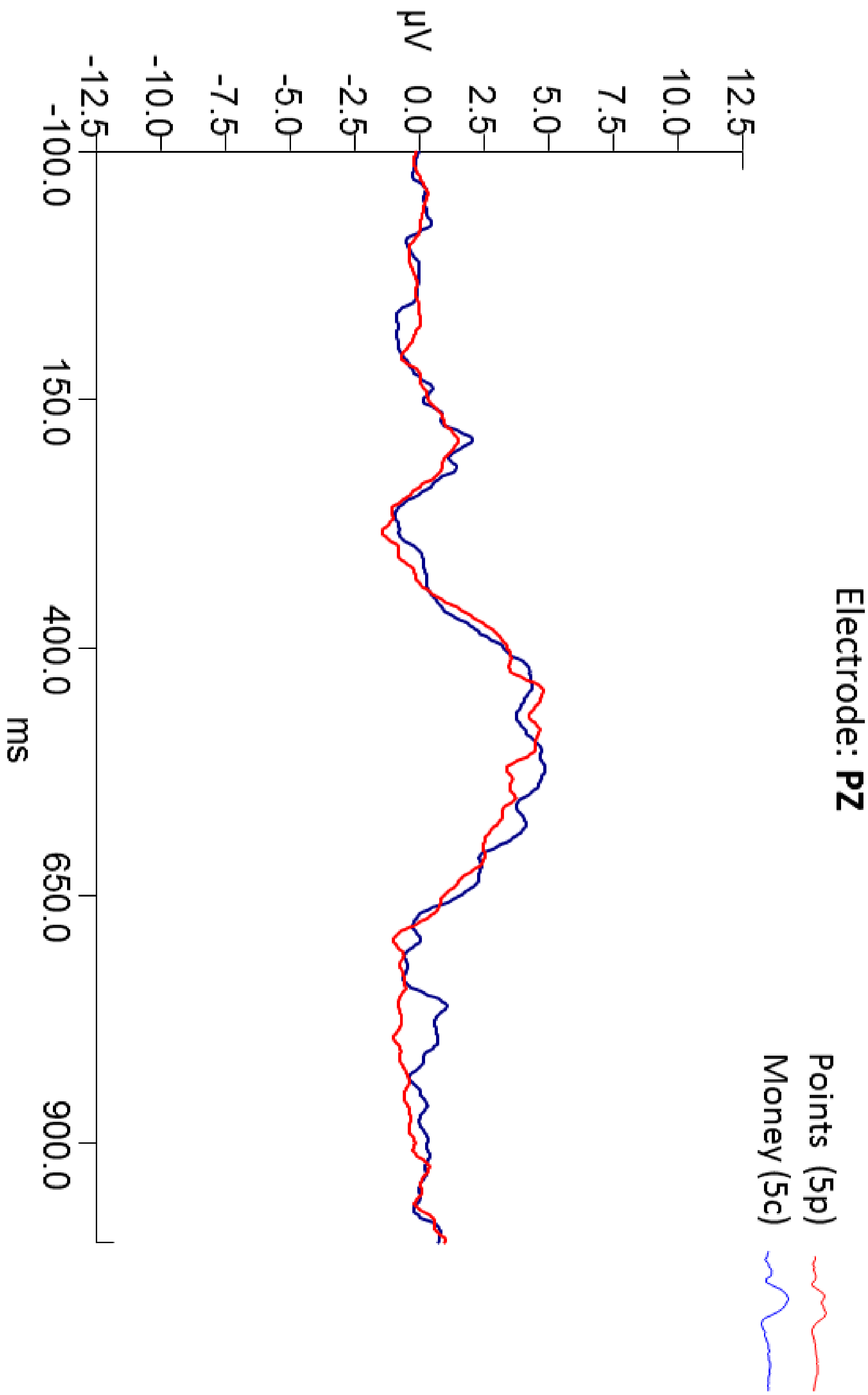

Figure 26 – Pattern Task Waveforms PZ Electrode

Main analyses. It was expected that response choices would be significantly related to executive functions of attention, inhibition, and set shifting and personality measures of appetitive motivation. As yielded components of executive functioning did not include a pure working memory measure, but included working memory and recall, overall Memory component scores were not used in the models. Also, as significant gender differences in overall personality components were identified, separate regression models were computed for each gender. Multiple linear regression models were conducted predicting percentage of pattern game choices from predictors including planning and set shifting (Executive), Inhibition, and Seeking entered simultaneously into the models. The model for women was significant and is shown in Table 13. Of the predictor variables, only Executive ($p < .05$) and Inhibition ($p < .01$) had significant zero-order correlations with percentage of choices to play the pattern learning task, although only Inhibition had a significant partial effect in the full model. The three predictor model was able to account for 32% of the variance in game choices for female participants, $F(3, 25) = 3.870$, $p = .021$, $\eta 2 = .56$.

Table 13.
Individual Differences in Game Choices Related to Executive Functioning and Appetitive Motivation for women (N = 29).

	Zero-Order *r*				β	sr^2	*B*
Variable	Seeking	Inhibit	Exec	Pattern%			
Executive				.370*	.17	.02	.015
Inhibit			.325*	.441**	.418*	.15	.039
Seeking		.123	-.237	-.259	-.270	.07	-.012
						Intercept =	.737
Mean	16.95	.528	1.19	.579			
SD	6.94	3.18	3.41	.299	R^2 =	.32*	

$*p < .05$, $**p < .01$

The model for men was significant and is shown in Table 14. Of the predictor variables, Inhibition ($p < .01$) had a significant zero-order correlation with percentage of choices to play the pattern learning task and had a significant partial effect in the full model. The three predictor model was able to account for 24% of the variance in game choices for male participants, $F(3, 23) = 2.380$, $p = .096$, $\eta2 = .24$.

Table 14.
Individual Differences in Game Choices Related to Executive Functioning and Appetitive Motivation for men (N = 27).

	Zero-Order *r*				β	sr^2	*B*
Variable	Seeking	Inhibit	Exec	Pattern%			
Executive				.082	.122	.01	.010
Inhibit			.107	-.466**	-.472*	.21	-.039
Seeking		-.163	.208	.150	.047	.002	.002
						Intercept =	.465
Mean	18.32	-.185	.837	..525			
SD	6.14	3.75	3.41	.312	R^2 =	.237*	

*$p < .05$, **$p < .01$

It was also hypothesized that neuropsychological measures of attention/working memory, inhibition, and set shifting would significantly predict neurophysiological measures of processing feedback indicative of goal conflicts in tasks eliciting a cognitive attentional set (pattern task), but not in tasks suggestive of emotion regulation attentional set (gambling task). Specifically, unit-weighted measures of executive functioning of inhibition and planning/categorization from the previously conducted components analysis were hypothesized to predict pattern task FN amplitudes, while a similar regression for these scores would not be significant for gambling task FN amplitudes. Due to gender differences in Inhibition identified in the previous models, these regressions were conducted separately for each gender. Inhibition and

Executive component scores were selected and entered simultaneously into a multiple linear regression model for predicting pattern task FN amplitudes, with FCZ chosen as a representative electrode. The overall model was not significant for women, $F(2, 26) = 0.121$, $p = .886$, $\eta 2 = .009$, or men, $F(2, 24) = 0.756$, $p = .480$, $\eta 2 = .059$, and neither predictor had a significant zero-order correlation with FN amplitudes in either model, suggesting that the pattern task FN was independent of neuropsychological functioning measures.

Inhibition and Executive component scores were then selected and entered simultaneously into a multiple linear regression model for predicting gambling task FN amplitudes, again with FCZ chosen as a representative electrode. The overall model for men was not significant, $F(2, 24) = 1.222$, $p = .312$, $\eta 2 = .092$, and neither predictor had a significant zero-order correlation with FN amplitudes. However, contrary to hypotheses, the model for women was significant and is shown in Table 15. Of the predictor variables, Inhibit had a significant zero-order correlation with gambling task FN amplitudes, although both predictors had a significant partial effect in the full model. The two predictor model was able to account for 22% of the variance in FCZ FN amplitudes, $F(2, 26) = 3.703$, $p = .038$, $\eta 2 = .22$.

Table 15.
Individual Differences in Gambling Task FN Amplitudes (FCZ) Related to Executive Functioning for women (N = 29).

	Zero-Order *r*			β	sr^2	*B*
Variable	Inhibit	Exec	FN Amp			
Executive			.256	.392*	.14	.501
Inhibit		.325*	-.290*	-.418*	.16	-.573
					Intercept =	-9.843
Mean	.528	1.19	-9.55			
SD	3.18	3.41	4.35	R^2 =	.22*	

*$p < .05$, **$p < .01$

This suggests that the gambling task FN amplitudes showed gender specific relationship with measures of executive functioning. For men, FN amplitudes were not significantly related for either task, while women showed significant relationships for gambling related FN amplitudes and measures of executive functioning. For the zero-order relationships, higher scores of inhibition predicted more negative FN amplitudes for women.

It was also expected that identified components of the personality measures would be significantly related to neurophysiological measures of feedback processing in tasks eliciting an emotion regulation attentional set (i.e. gambling), but not tasks eliciting a cognitive attentional set (i.e., pattern learning tasks). Multiple linear regression models were conducted separately for each gender, predicting FN amplitude (again at FCZ) for each task condition. The three personality components of Seeking, Suppression, and Maintenance were entered simultaneously into each model. For the pattern learning task amplitudes, the overall three predictor model for women was not significant, $F(3, 25) = 1.438$, $p = .255$, $\eta 2 = .147$, and none of the predictors had a significant zero-order correlation with FN amplitudes. Similarly, the overall model for men was not significant, $F(3, 23) = 1.870$, $p = .163$, $\eta 2 = .196$, although in this case, Maintenance had a significant zero-order correlation ($p < .05$) with FN amplitudes. This suggests that the pattern task FN was relatively independent of the personality components.

For the gambling task FN amplitudes, the overall three predictor model for women was not significant, $F(3, 25) = 1.194$, $p = .332$, $\eta 2 = .125$, and none of the predictors had a significant zero-order correlation with FN amplitudes. However, the overall model for men was significant and is shown in Table 16. Of the predictor variables, only Maintenance ($p < .01$) had a significant zero-order correlation with gambling task FN amplitudes, and had a significant partial effect in the full model. The three predictor model was able to account for 29% of the variance in FCZ FN amplitudes, $F(3, 23) = 3.122$, $p = .046$, $\eta 2 = .29$.

Table 16.
Individual Differences in FN Amplitudes (FCZ) related to Components of Personality and Appetitive Motivation for Men (N = 27).

Variable	Zero-Order *r*				β	*sr*^{2}	*B*
	Seeking	Suppress	Maintain	FN AMP			
Maintenance				-.509*	-.955**	.28	-.561
Suppression			-.273	.041	-.163	.01	-.097
Seeking		-.105	.177	.054	.090	.02	.143
						Intercept =	-8.925
Mean	18.32	-2.67	.579	-7.39			
SD	6.13	2.31	2.28	3.88	R^2 =	.289*	

*$p < .05$, **$p < .01$

Discussion

Findings partially support the hypotheses of the relationships between neurophysiological markers of cognitive and affective control and personality and neurocognitive functioning. Investigating engagement of attentional set between the tasks supported that neurocognitive functioning was related to response selections. While no direct measures of HRV were available to corroborate the elicitation of attentional set for the tasks, the results of the previous study of this work (Chapter 3) and these results suggest possible gender differences in attentional set elicitation. More specifically, a measure of inhibition was significantly related to behavioral measures of task preference during the hybrid task. In this case, higher scores on inhibition measures predicted greater selections of the pattern tasks for women, but lower selections of the pattern task for men. Also, executive functions of planning and concept formation significantly predicted decisions to play the pattern task for women, but did not predict response selections for men. It may be that female participants during this procedure were more cognitively engaged and that those women with higher scores on executive functioning measures preferred a cognitively engaging task, over a task with randomized outcomes, regardless of the possibility of winning more money through gambling task selection. This selection bias could also reflect a tendency for female participants to desire more control of outcomes. For men, the opposite relationships were identified, with executive functioning having little relationship with response choices and inhibition predicting opposite game selections from women. In this case, these relationships could represent little desire for cognitive engagement or a bias for seeking monetary rewards for male participants, regardless of the level of outcome control.

When relationships between neurocognitive and personality components with FN responsivity to errors during the tasks were investigated, overall results found that neither neurocognitive component scores nor personality component scores predicted FN responses to errors during the pattern task for either gender. This suggests that FN responses during this task were not significantly related to either executive functioning or personality, and may simply represent low-level processing of the valence of results. However, findings also identified gender differences in neurophysiological responses to errors during the gambling task, suggesting that the FN functioned differently between the two tasks, and was differentially related to attentional set elicitation between genders. For men, higher Maintenance scores were predictive of lower FN amplitudes on the gambling task. This suggests that men were more reactive to negative feedback when their tendency to prefer stability is high, while women showed no relationships between personality and FN responsivity during the gambling task. For women, it was the neurocognitive functioning components that significantly predicted FN amplitudes during the gambling task, with higher scores on the Inhibition component predicting a much higher error response (lower FN amplitudes) and higher scores on the Executive component predicting lower error responses (higher FN amplitudes). Taken together, these findings suggest that gambling task FN responses in men were much more closely related to personality and appetitive motivation, while women gambling task FN responses were more related to neurocognitive functioning.

The engagement of cognitive resources for women during the gambling task supports the overall cascade of control model of feedback processing relationships with executive functions (Banich, 2009). In this case higher rates of executive functioning showed lower FN amplitudes and thus a lower response to negative feedback. As the measures utilized in the current study were heavily involved in planning and categorization, these results suggested that individuals better able to make outcome predictions may have showed greater expectation of losses and an attenuation of processing outcome valences. In addition, higher inhibition scores were related to lower FN amplitudes and greater responses to error feedback. This again makes sense with the function of inhibition in behavioral outcomes on the D-KEFS color word subtest from which the scores were quantified. These tasks required response speed and inhibition of the normal response tendency of word reading (as well as switching in the final task). Those better able to inhibit these responses during the color-word task showed greater cingulate cortex identification of errors. Perhaps this could represent individual differences in the ability to recognize errors, which provides the overall feedback to the executive system to allow swift and more efficient selection of behavioral responses that adequately satisfy task expectations.

Conclusions and Directions for Future Research

Overall, these results provide some support regarding the differences in attentional set engagement to the tasks, but that this operated differently by genders. The findings of inhibition being related to greater choices of pattern game participation for women and greater gambling task participation for men, suggest that men and women were avoidant (or selective) of the different tasks, with men avoiding the more cognitively engaging task, while women avoided the more affectively engaging task. However, for this subclinical sample, pattern task feedback processing did not support cognitive engagement and direct relationships between neurocognitive functioning or personality and cognitive control. However, feedback processing in the gambling task did support that men were more affectively engaged, while women were more cognitively engaged in feedback processing. When interpreted with the identified relationship between anxiety and inhibition, this suggests that anxiety and inhibition were related to avoidance of the gambling task for women, and that women were more cognitively engaged across both tasks, suggesting a tendency to utilize neurocognitive resources in response selection for the pattern task and feedback processing in the gambling task, perhaps in an effort to avoid affective responding. This also suggests that male variance in feedback processing was somewhat related to personality and suggests the engagement of an affective attentional set in the gambling task for men.

Overall, these results suggest little utility in these computed measures of neurocognitive functioning in identifying attentional set or predicting feedback processing for these tasks. One possibility for this lack of findings may be due to the differentiation of cold, prefrontal cortex related executive functions and hot, orbitofrontal executive functions. The measures of executive functioning utilized in the current task were more closely related to cold executive functions. Perhaps quantification of hot executive functioning, or making decisions from reward learning and affective response information, using tasks such as the Iowa Gambling Task in follow up research may show greater direct relationships between hot executive functioning and FN responses to gambling during a gambling task.

However, as these participants reported subclinical anxiety, it may be that overall relationships and engagement of attentional set on these tasks were not clearly defined. As these participants reported somewhat higher than average cognitive flexibility (mean Executive scores +0.8 and +1.2z by gender), participants may have been flexible in their approaches to the tasks and able to shift perspectives between cognitive and affective responses to the tasks. Future research should investigate these differences using clinical anxiety and/or depressed samples, which are known to have cognitive biases and more difficulties with cognitive flexibility (Beck, 2008), suggesting that relationships may be more clearly defined in these populations.

Chapter 5: Clinical Anxiety and Decision Making

Literature Review

The final investigation in this work was undertaken to identify the utility of using cognitive neuroscience and electrophysiological techniques to identify information processing biases predicted by the overall CBT etiological model of mental illness. As reviewed previously in the overall introduction, the cognitive model proposes that individuals with a psychological disorder will demonstrate biases in how they perceive situations, differences in how they affectively respond to those situations, and show distortions of cognitive information processing through distortions in thinking and dysfunctional beliefs (Beck, 2008).

This cognitive information processing using either the classical linear IPT model or the more distributed PDP model is hampered by unclear relationships with the overwhelming complexity of the nervous system, and they represent more complex approximations than previous, simpler theories. Identification of these cognitive biases experimentally and linking those biases with electrophysiological markers of brain activity could greatly aid in building these models to more closely represent the actual brain based processing. Previous studies looking for these biases in depression have been instrumental in understanding that depression may involve reductions in the ability of prefrontal circuitry to down-regulate amygdalar processing of negative stimuli (Johnston, van Rectum, Uri, Kalyn, & Davidson, 2007 ; Siegel et al., 2007). In addition to prefrontal regulation, abnormal cingulate cortex error responses have been identified in samples with depressive disorders (Pizzagalli, Peccoraldo Davidson, & Cohen, 2006). These findings suggest executive functioning differences between individuals with depression and normal controls, when processing negative stimuli or error feedback. Very similar to the role of the prefrontal and cingulate cortex in exerting cognitive control of ongoing decision making on a task (i.e. cascade of control model; Banich, 2009), these areas are implicated in parallel emotion regulation or emotional control related to decision making for affectively arousing tasks (Davidson, 2000). In addition, this parallel process has been proposed to be engaged in all decision making, as affective state information has been shown to affect decision making at each level of the process, including identification of stimuli emotional salience for emotional context, making the decision, and outcome evaluation (Gray, 1990; Izard, 1993; LeDoux, 1987). This parallel regulation suggests that any study attempting to investigate decision making without including affective states and responses to stimuli are incomplete (Ashby, Isen, & Turken, 1999).

However, this does not suggest that all decision making outcomes are greatly affected by affective regulation, just that emotionally salient contexts, stimuli, and affective responses to a task would increase the use of emotional processing and control. Thus, it is possible that psychological disturbances, and their cognitive biases, could predispose engagement of this system to a much greater extent than normal controls. In fact, deficits in cognitive control have been described in a wide variety of psychiatric disorders including schizophrenia (Kerns et al., 2005), depression (Melcher, Falkai, & Gruber, 2008), and anxiety disorders (Etkin, Prater, Hoeft, Menon, & Schatzberg, 2010; Osinsky, Alexander, Gebhardt, & Hennig, 2010), suggesting that perhaps cognitive control was attenuated to divert resources to emotional control. Focusing more intently on anxiety disorders, these can be conceptualized as disturbances in the excessive experience of anxiety (American Psychiatric Association, 2000). Anxiety is a normal human behavior though to aid in maintaining readiness to respond to threat and negative stimuli and have behavioral flexibility (LeDoux, 1996, Ninan, 1999). As reviewed previously, the neurophysiological basis of this anxiety includes the hypothesized BAS, BIS, and FFFS systems from reinforcement sensitivity theory, and the central nucleus of the amygdala (CnA), regulating different aspects of the anxiety response and engagement of behavioral responses to an activating stimulus (Gray & McNaughton, 2000; Ninan, 1999). With the aforementioned down-regulation of emotional responsivity by the frontal and orbitofrontal cortices, including direct down-regulation of the amygdala, excessive anxiety symptoms could represent a reduction in this frontal lobe regulation of limbic responses and result in the loss of cognitive flexibility, cognitive control, and behavioral response limitations inherent in anxiety disorders (Ninan, 1999).

Using the known relationships between cingulate cortex performance monitoring and recruitment of cognitive resources for decision making following error or goal conflict detection (Botvinick et al., 2001; Egner, 2011; Egner & Hirsch, 2005a, 2005b; Kearns, 2006), neurophysiological markers of cingulate performance monitoring, such as the feedback negativity (FN), could be used as a physiological correlate for determining cognitive biases between psychiatrically disturbed and normal control samples. One method of determining this cognitive bias is through statistical decision making theories. The behavioral tasks of pattern learning and gambling behavior utilized throughout this work have generally supported the hypotheses that gambling tasks elicit more autonomic nervous system activity and more negative FN amplitudes, than a pattern learning task framed as a memory task requiring cognitive ability, with the caveat of some gender differences in this engagement. Conferring a monetary advantage to the gambling task over the pattern learning task, and allowing a choice between these tasks, would allow behaviors focused on either maximizing attaining rewards regardless of increased affective elicitation or the frequency of reinforcers, or maximizing positive reinforcement while avoiding affective elicitation, regardless of less reward. Thus, responding maximizing monetary rewards should show greater likelihood of choosing the gambling task, while responding maximizing wins and avoiding loss feedback should show greater likelihood of choosing the pattern task.

If we use clinical anxiety as our physiological state variable in the statistical decision making likelihood models reviewed previously, the likelihood of choosing pattern (A), or $\sum_{i=1}^{n} \log(\frac{P(A1,A2 \ldots Ai|anxiety)}{P(A1,A2,\ldots,Ai|normal)}$, should be greater than the likelihood of choosing gambling (B), or $\sum_{i=1}^{n} \log(\frac{P(B1,B2 \ldots Bi|anxiety)}{P(B1,B2,\ldots,Bi|normal)}$. Summed across tasks, a bias to avoid affective responses to a task for the anxiety group should show significantly greater selections to play the pattern task over the gambling task.

- *Hypothesis 4 – The presence of clinical anxiety will increase behavioral level responses focusing on affect regulation through seeking reward frequency over cognitive control through seeking maximizing rewards, as reflected by group differences in greater pattern/gambling task ratios for the GAD group over normal controls, with greater FN responsivity to errors for the GAD group over normal controls.*

Procedure

Participant recruitment and screening. The current study was undertaken as a pilot study to determine the feasibility of a large scale multivariate study investigating neurocognitive and personality contributors in clinical anxiety samples. A series of one-way ANOVAs were conducted to determine the effects of clinical levels of a single representative subset of anxiety symptomatology as defined by the current (at the time of data collection) diagnostic nosology (DSM-IV-TR) on outcome variables. Effect sizes reported within previous similar designs suggests a large estimation of effect; Cohen’s *d* estimates for power analyses were set at 0.8. Sample sizes were computed through power analysis (Figure 27), providing an overall sample size of 70, with 35 participants in each group to achieve 95% power.

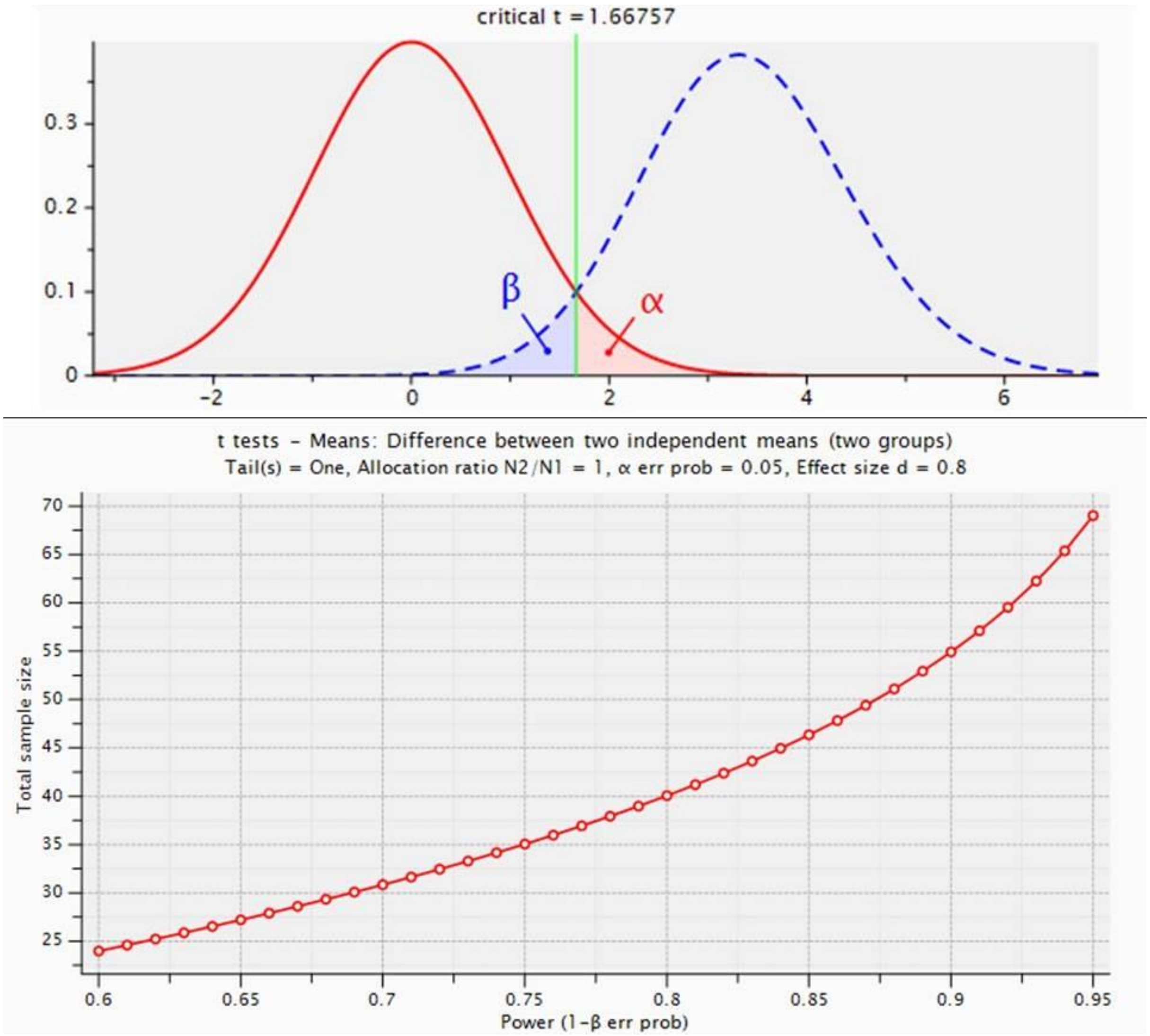

Figure 27 - G*Power A-priori Power Analysis of one-way ANOVAs

Undergraduate participants were recruited utilizing posted advertisements requesting participation from students experiencing anxiety symptomology (Appendix A). All participants were right-handed and screened for normal or corrected-to-normal vision, no history of neurological disorders, or use of any substances, that might interfere with alertness or electrophysiological measurement. In addition, subjects were rescheduled if they indicated current daytime somnolescence or disturbed sleep the night before reporting for the study. In order to limit any influence of monetary rewards on participant selection, participants were only informed that they would be receiving both cash rewards based on performance and entry into a raffle for a $50 cash prize after disclosing no disqualifying information. All participants provided written informed consent prior to the start of the study and the study was approved by the University and Medical Center Institutional Review Board (UMCIRB), prior to initiating screening procedures (Appendix A).

Participants completed a number of screening procedures similar to the previous studies, including completion of the South Oaks Gambling Screen (SOGS; Lesieur & Blume, 1987), with no participants being excluded for exceeding the standard cutoff of 5 on the measure. All participants were also screened using selected modules from the Anxiety-Disorder Interview Schedule for the DSM-IV-TR (ADIS-IV; Brown, Di Nardo, & Barlow, 1994). Participants also completed the Beck Depression Inventory–II (BDI-II; Beck, Steer, & Brown, 1996), with scores at or above 13 used to select participants for additional screenings for symptoms of depression. No participant reported affirmatively to the BDI-II suicidal ideation item (Item #9), precluding the need for initiation of suicide assessment and care procedures or emergency care management. Participant scores ranged from 0 to 32 (M = 11.32, SD = 5.3), with eleven participants requiring additional screening and were administered selected depression modules from the ADIS-IV.

Of these participants, nine were identified as reporting diagnostic criteria supportive of possible psychological difficulties other than GAD and were excluded from further participation and provided referrals to either the university counseling center, or outside providers if requested. As mentioned previously, three participants meeting DSM-IV-TR diagnostic criteria for generalized anxiety disorder were recruited following identical screening procedures from the third study of this work (Chapter 4). Eight additional participants reported previous psychiatric diagnoses at interview. After screening procedures, only 14 adult undergraduate participants met criteria for GAD and were retained in the GAD group (11 women, 3 men). Participant ages ranged from 18 to 24 years (*M* = 19.8, *SD* = 1.58). While this is below the 35 participants estimated for 95% power, time limitations would not permit additional recruitment. Therefore, 14 normal control participants were recruited (11 women, 3 men), with a mean age of 18.9 years (*SD* = 0.77 years). As significant gender differences were obtained in previous studies, groups were established with identical gender composition to limit gender effects on between group analyses. Overall education level of the participants were also matched with a mean of 13.36 years for the control group (*SD* = 0.63 years) and 13.79 years for the GAD sample (*SD* = 0.89 years) and ranged from 13 to 15 years for both groups.

Between group differences on screening measures were not found for gambling scores. A one-way ANOVA on SOGS scores between groups was not significant, $F(1, 26) = 1.444$, $p = .240$. However, a one-way ANOVA of BDI-II scores identified between group differences on depressive symptomology, with significantly higher depression scores for the GAD group ($M = 8.93$, $SD = 6.42$) than the control group ($M = 3.71$, $SD = 3.81$), $F(1, 26) = 6.837$, $p = .015$, $d = 1.02$. As expected based on symptomology used to define groups, trait anxiety scores were significantly different between the groups (Figure 28), with significantly higher STAI-T scores for the GAD group ($M = 50.07$, $SD = 6.03$) than the control group ($M = 27.64$, $SD = 4.63$), $F(1, 26) = 121.72$, $p < .001$, $d = 4.33$. However, it was unexpected for there to be no group overlap on this measure and a mean split of such magnitude. It is likely that the small sample size created an artificially high group difference on this measure that is not reflective of performance of larger samples with clinical anxiety (Spielberger, 1983). This does suggest that the groups utilized in the current study represent vastly different levels of self-reported anxiety, possibly due to recruitment methods attracting participants with higher symptom levels, and reduces the generalizability of any findings.

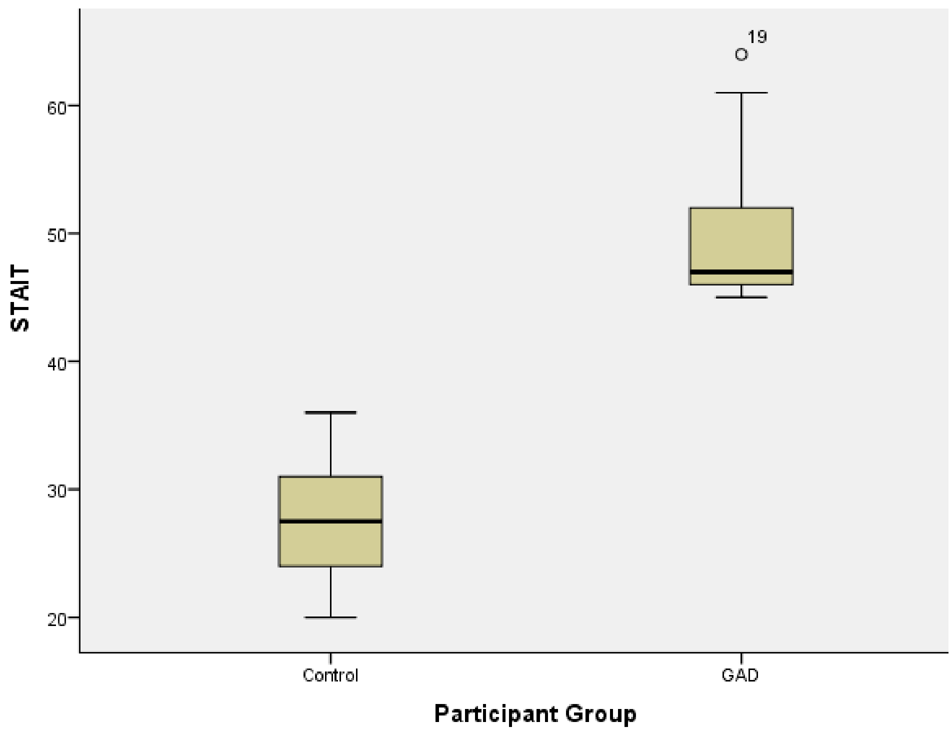

Figure 28 – Box and Whisker's plots of STAI-T Scores

Experimental procedure. All procedures were identical to those utilized in the third study of this work (Chapter 4). Participants retained following screening criteria completed the remainder of the personality inventories including the State-Trait Anxiety Inventory – Form Y (STAI; Spielberger, 1983), the Positive and Negative Affective Schedule (PANAS; Watson, Clark, & Tellegen, 1988) presented as a trait measure, Carver and White's (1994) BIS and BAS scales, the Appetitive Motivation Scale (AMS; Jackson & Smillie, 2004), and the Mini-IPIP (International Personality Item Pool; Donnellan, Osald, Baird, & Lucas, 2006), with the slight change to item 19 noted previously.

Although not all measures were eventually included in statistical analyses during the previous study, participants completed identical neuropsychological batteries to the previous study, including the Test of Premorbid Functioning from the Advanced Clinical Solutions (TOPF; NCS Pearson Corporation, 2009), the California Verbal Learning Test – II (CVLT-II; Delis, Kramer, Kaplan, & Ober, 2000), Digit Span subtest from the Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV; Wechsler, 2008),the Ruff 2 & 7 Selective Attention Test (Ruff & Allen, 1996), parts A and B of the Trail Making Test (TMT; Reitan, 1958), the Controlled Oral Word Association Test (COWAT) and category fluency (animals) from Benton and Hamsher (1976). Participants also completed selected subtests from the Delis-Kaplan Executive Function System (D-KERFS; Delis, Kaplan, & Kramer, 2001) including the Sorting Test, Color-Word Interference Test, and Tower Test.

All preparation for electrophysiological recording and sequence of recording tasks were identical to those outlined for the third study of this work (Chapter 4), including baseline spectral power recording, HRV recording, and ERP recording and computation from the sequence of three tasks. All tasks used identical reinforcement probabilities and magnitudes.

Results

Electrophysiology results. ERPs were extracted from continuous measurements using 1100ms epoch windows, including a 100ms pre-feedback baseline and the 1000ms following feedback presentation following electro-ocular movement corrections. All files were digitally filtered using a 6 dB band-pass filter (0.1 to 100Hz) and baseline corrected relative to the 100ms pre-feedback baseline. Grand average waveforms were averaged from total loss and total win feedback across all trials and conditions for the FZ, CZ, and PZ electrodes (Figure 29). Overall difference waves (Figure 30) for each electrode revealed a negative deflection in the wave similar to the previous study between 225 and 325 ms, consistent with a FN response.

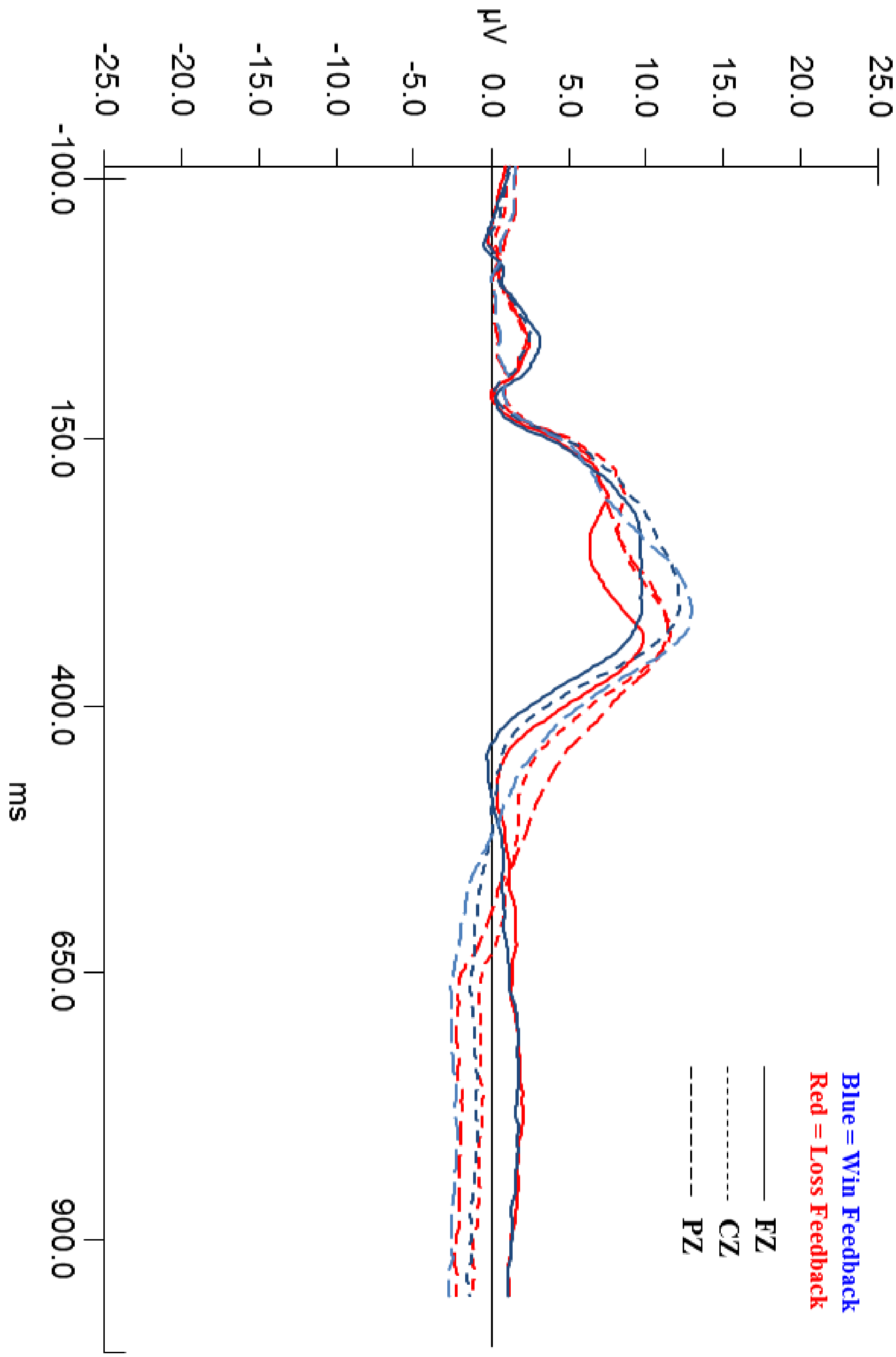

Figure 29 – Grand Average Waveforms

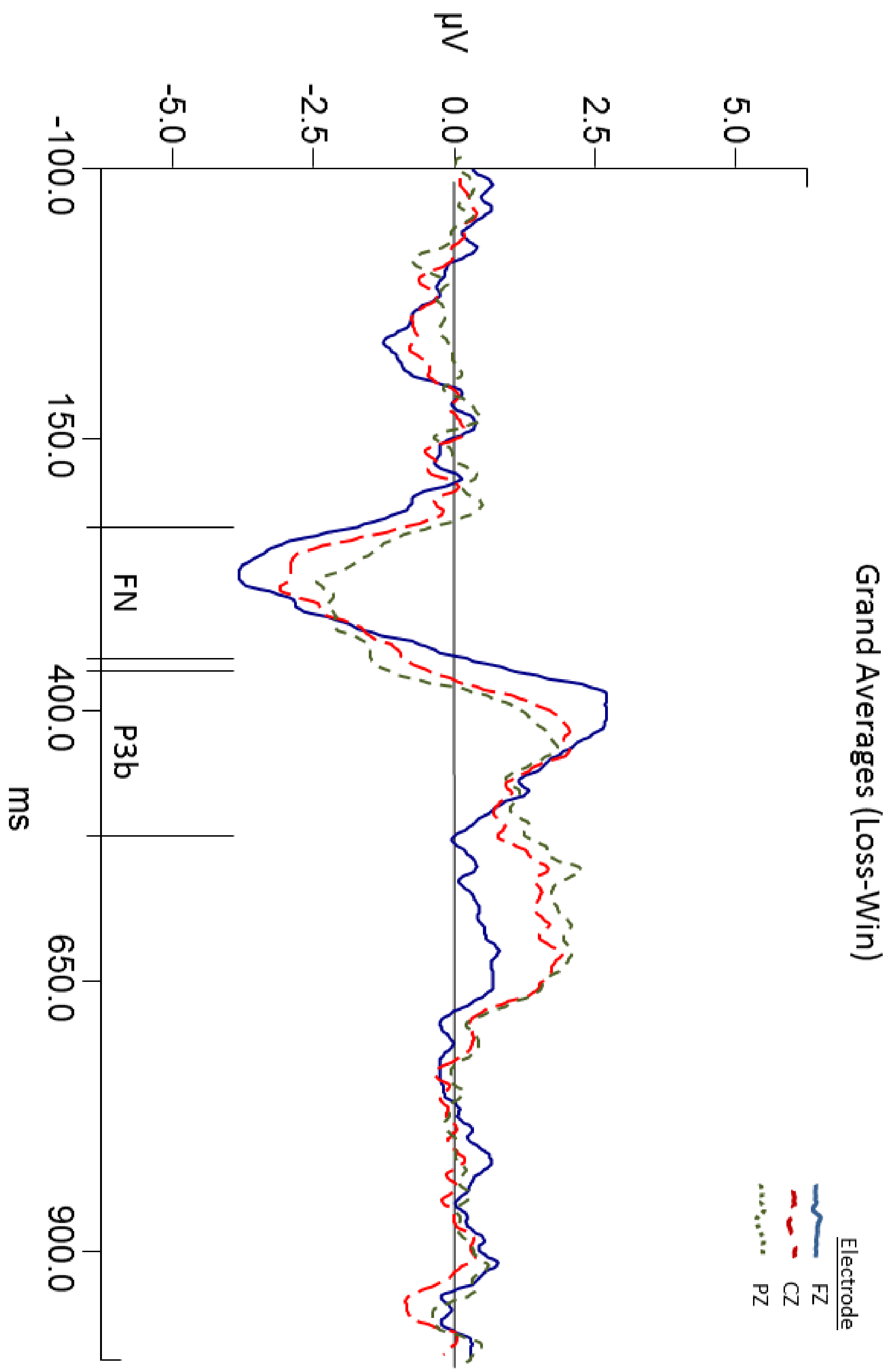

Figure 30 – Grand Average Difference Waveforms

Between-group one way ANOVAs on FZ FN amplitudes for both the pattern and gambling tasks were conducted, finding no significant differences for the pattern task, $F(1, 26) = 2.372$, $p = .136$, or for the gambling task, $F(1, 26) = 3.072$, $p = .091$. While these differences were not statistically significant, the mean amplitude difference for the gambling task was 2.7 μV more negative for the GAD group (M = -7.587 μV, SD = -1.75 μV) than the control group (M = -4.810 μV, SD = -1.68 μV), and the effect size was moderate, $d = 0.70$. The similar pattern task mean difference was only 1.1 μV more negative for the GAD group. These findings support the feasibility of a larger study utilizing these tasks with clinical samples as a means to elicit between group FN differences.

Behavioral results. An one-way ANOVA of scores from the pattern task was not significant, $F(1, 26) = 0.240$, $p = .629$, showing no group differences in gambling scores, with the GAD group mean score of 215.14 (SD = 72.19) and the control group with a mean score of 227.14 (SD = 58.36). The percentage of correct adaptations were also not significantly different between the groups, $F(1, 26) = .816$, $p = .337$, with the control group showing a mean of 77% corrections (SD = .234) and the GAD group with a mean of 69% corrections (SD = .246).

However, an one-way ANOVA of scores from the gambling task showed significant differences in gambling performance between the groups (although correct responses were randomized), $F(1, 26) = 6.11$, $p = .020$, $d = 0.97$, with the GAD group winning a mean total of \$1.28 (SD = \$0.46) and the control group winning a mean total of \$0.79 (SD = \$0.58). The hybrid task allowed participants to choose gambling or pattern task performance and a percentage of pattern choices were computed for each participant, ranging from 0% (all gambling) to 100% (all pattern). This significant difference in gambling task performance was thought to have possibly significantly affected game choice during the hybrid task. A single linear regression model predicting percentage of pattern choices from gambling task performance was not significant, $F(1, 26) = 0.578$, $p = 0.45$, $d = .29$, suggesting these group differences in gambling task reinforcement did not significantly affect hybrid game choices.

A one-way ANOVA of overall monetary reinforcement on the hybrid task was not significant, $F(1, 26) = 3.64$, $p = .067$, $d = 0.74$, with the control group winning an average of \$2.77 (*SD* = \$0.53) and the GAD group winning an average of \$2.41 (*SD* = \$0.44). While not statistically significant, the effect size for this difference was medium to large and suggests the need for an adequately powered study. This monetary advantage of the control group was likely a result of game choices, as the control group played the gambling task a higher number of times, playing a mean of 52% pattern games (*SD* = 27%), while the GAD group played a mean of 69% pattern games (*SD* = 24%). While this difference was not statistically significant, $F(1, 26) = 3.22$, $p = .084$, $d = .70$, effect sizes were again medium to large suggesting that an adequately powered study is needed to investigate these differences further. As hypothesized, the GAD group elected to play the pattern game at a higher rate than the control group, even though overall GAD group reinforcement in the previous gambling task was significantly higher than the control group, and the gambling game in the hybrid task had a monetary advantage. This supports the main hypothesis of decision making related to engagement of an affect regulation attentional set and avoidance of the higher rates of negative feedback for the clinical anxiety group.

Affective response to task. Similar to the previous study, differentiation of HRV responses to pattern or gambling tasks was not possible. An one-way ANOVA of baseline LF/HF HRV ratios between groups did not find a significant difference on sympathetic/parasympathetic nervous system balance at rest, $F(1, 26) = 0.245$, $p = .625$.

Similarly, there was no overall difference in response to the pattern/gambling second measurement period, $F(1, 26) = 1.898$, $p = 0.180$, or in response to the hybrid task, $F(1, 26) = 1.677$, $p = 0.21$.

Personality results. Independent samples t-tests were computed on the unit-weighted components of personality outlined throughout this work to investigate between group differences on these measures. Significant between group differences were not found for the Seeking measure, $t(26) = 0.819$, $p = .420$. However, significant differences with a large effect were found for Maintenance, $t(26) = 2.673$, $p = .013$, $d = 1.04$, with the GAD group showing significantly lower scores. The GAD group had significantly higher scores with a very large effect size for Suppression, $t(26) = 8.656$, $p < .001$, $d = 3.40$.

Neuropsychological results. Between group differences on measures of neuropsychological functioning were undertaken to help identify significant performance differences to aid in an understanding of task specific performance differences. It is hoped that investigating these group differences by test will aid in the understanding of neuropsychological performance for these groups to help inform clinical neuropsychological practice. The computed unit-weighted components created from the specific test data planned for main analyses will serve to better inform theory, and is not thought to be redundant analyses due to the clinical nature of the present comparisons. Many of these measures have normative data separated by gender, however, any gender based differences are already accounted for in the scored data. Thus, tests of scaled, T, or standard scored test data were entered into independent samples *t*-tests by clinical group. The GAD group performed significantly faster (M = 60T, $SD = 2.28$) than the control group (M = 48T, $SD = 4.17$) on Trail Making Test A T-scores, $t(26) = 2.198$, $p = .037$, $d = 0.86$. Of note, no other significant differences between groups were found on main test scores. The only other significant difference was found on number of errors made on the inhibition trial (non-switching) for the D-KEFS Color-Word Interference Test, with the GAD group making a significantly lower number of errors (*M* = 11 SS, *SD* = 2.13) than the control group (*M* = 8 SS, *SD* = 3.68), $t(26) = 2.703$, $p = .012$, $d = 1.06$. Of note, similar mean differences were observed for the switching trail number of errors, with the GAD group (*M* = 10.6 SS, *SD* = 2.21) showing fewer errors than the control group (*M* = 8.71 SS, *SD* = 3.47), although these differences were not statistically significant, $t(26) = 1.754$, $p = .091$, $d = 0.69$.

Prospective analyses. While the current study was designed for between group differences, predictive models were constructed for the significant differences found for FN amplitudes and game choices. Similar to the previous predictive models constructed for the subclinical sample, unit-weighted component measures were used in the new models, including the neuropsychological components related to planning and set shifting (Executive) and Inhibition, and the personality components of Seeking, Maintenance, and Suppression. However, unlike the previous models, the identical gender makeup of the groups and the low sample sizes precluded models for each gender (a male group would only have 3 participants), and separate models were constructed for both groups. To reduce the overall number of comparisons, FCZ was again chosen as a representative mid-frontal electrode for FN analyses.

Scores on Executive, Inhibition, and Seeking were entered simultaneously into multiple regression models predicting percentage of pattern game choices for both the GAD and control groups. The model predicting game choices for the control group was not significant, $F(3, 10) = 0.788$, $p = .528$, and none of the predictors had a significant zero-order correlation with the outcome variable. Similarly, the model predicting game choices for the GAD group was not significant, $F(3, 10) = 1.080$, $p = .401$, and none of the predictors had a significant zero-order correlation with the outcome variable.

Scores on Executive and Inhibition were entered simultaneously into multiple regression models predicting pattern task FN amplitudes at the FCZ electrode for both the GAD and control groups. The model predicting pattern task FCZ FN amplitudes for the control group was not significant, $F(2, 11) = 0.460$, $p = .643$, and neither of the predictors had a significant zero-order correlation with the outcome variable. The model pattern task FCZ FN amplitudes for the GAD group was not significant, $F(2, 11) = 0.902$, $p = .434$, and neither of the predictors had a significant zero-order correlation with the outcome variable. Identical predictors were then entered simultaneously into multiple regression models predicting gambling task FN amplitudes at the FCZ electrode for both the GAD and control groups. The model predicting gambling task FCZ FN amplitudes for the control group was not significant, $F(2, 11) = 1.715$, $p = .225$, and neither of the predictors had a significant zero-order correlation with the outcome variable. The model gambling task FCZ FN amplitudes for the GAD group was not significant, $F(2, 11) = 0.562$, $p = .585$, and neither of the predictors had a significant zero-order correlation with the outcome variable.

The three personality components of Seeking, Suppression, and Maintenance were entered simultaneously into regression models predicting FN amplitude (again at FCZ) for each task condition and participant group. The model predicting pattern task FCZ FN amplitudes for the control group was not significant, $F(3, 10) = 0.788$, $p = .528$, and none of the predictors had a significant zero-order correlation with the outcome variable. The model predicting pattern task FCZ FN amplitudes for the GAD group was also not significant, $F(3, 10) = 1.417$, $p = .295$, and none of the predictors had a significant zero-order correlation with the outcome variable.

Identical predictors were then entered simultaneously into multiple regression models predicting gambling task FN amplitudes at the FCZ electrode for both the GAD and control groups. The model predicting gambling task FCZ FN amplitudes for the control group was not significant, $F(3, 10) = 0.735$, $p = .554$, and none of the predictors had a significant zero-order correlation with the outcome variable. The model gambling task FCZ FN amplitudes for the GAD group was not significant, $F(3, 10) = 0.122$, $p = .945$, and none of the predictors had a significant zero-order correlation with the outcome variable.

Discussion

These results support that individuals with generalized anxiety disorder (GAD) show a bias in processing error related stimuli, with more negative FN amplitudes, suggestive of more intense reactivity to negative stimuli than normal controls. As the FN is a subtraction, there are three possible interpretations of these findings. The first is that there is less of a positive response to positive feedback in the GAD sample. The second is that there is more of a negative response to negative feedback in the GAD sample. Finally, the third interpretation is that both of these effects are occurring simultaneously. Determining this is difficult, however, there are some known associations between eliciting the FN using positive feedback that violate reward expectations, with the largest FN responses occurring for unexpected negative feedback when compared to unexpected positive feedback (Gibson, et al., 2002; Hajcak et al., 2007; Nieuwenhuis et al., 2005; Nieuwenhuis et al., 2002). These studies suggest that the FN is not simply a response to the objective loss of resources but a reaction to predicted outcomes.

Taking this and applying it to the behavioral manifestations of depression and anxiety, one could argue that individuals in these groups are more reactive to negative stimuli, or have a reduced response to positive stimuli. In the case of depression, a recent study related gambling task elicited FN amplitudes to anhedonia in a sample of patients with major depression, finding reduced FN responses related to depression and anhedonia severity (Liu et al., 2013). While these authors suggested this could be due to reduced dopaminergic response to reward-processing it also could represent lower expectation of positive outcomes and negative feedback being less surprising to the participants. These results argue against the FN group differences being due to reductions in prefrontal down-regulation of amygdalar processing of negative stimuli in depressed patients (Johnston, van Rectum, Uri, Kalyn, & Davidson, 2007; Siegel et al., 2007), as one would expect a more negative FN response to this relative increase in amygdalar activity.

However, this bias suggested for depressed patients may not be occurring in the anxiety sample in this study. An anxiety sample might not predict greater negative outcomes, but simply be more vigilant or reactive to negative outcomes. While not statistically significant, there was a considerable increase in FN responsivity in the GAD sample compared to controls. As cingulate cortex performance monitoring is known to be related to recruitment of cognitive resources for decision making (Botvinick et al., 2001; Egner, 2011; Egner & Hirsch, 2005a, 2005b; Kearns, 2006), and cognitive control deficits are shown in the anxiety disorders (Etkin, Prater, Hoeft, Menon, & Schatzberg, 2010; Osinsky, Alexander, Gebhardt, & Hennig, 2010), this increased FN response may be the manifestation of greater reactivity due to vigilance and an attempt to recruit additional cognitive resources. Another possible interpretation is that this represents greater affective reactivity to the negative outcomes. It is noteworthy that these differences were only manifest during a gambling task that previously showed significantly higher affective elicitation, and that much lower mean amplitude differences were found in a pattern learning task. Based on these previous results, the gambling task elicited more of a reaction to negative stimuli, regardless of the inability to make objective reward predictions due to the random nature of the feedback, supporting greater engagement of affective responses to the task, and supportive of a reduced orbitofrontal down-regulation of amygdalar activity in the GAD sample. When then given the choice of engaging in these tasks, the GAD group showed higher rates of choosing the pattern task than normal controls, even though this task had less monetary reinforcement. This suggests that the GAD group showed some behavioral bias to avoid the task eliciting affective responses.

These biases in behavioral choices and in FN amplitudes support differences between the GAD group and the control group in how they perceived the gambling task or the negative feedback from losses. The overall conceptualization of the affective information processing models suggests that this group bias could originate from many different elements of the system, including overall differences in perception of the salience of the emotional context of gambling, basic perceptual differences regarding the stimuli, and differences in affective responsivity to the task (Gray, 1990; Izard, 1993; LeDoux, 1987). In this study, between-group differences were not found for the HRV measurements, however, due to task speed, specific differentiation of affective responses between the pattern and gambling tasks was not possible. However, the other two elements, the emotional context and stimuli perceptual differences, remain possibilities. While the tasks in this case used identical stimuli, it is possible that there were differences in the perceptual salience of the negative stimuli in the more affective arousing gambling task, although this may also have been due to the overall emotional salience of the context of the gambling task through engaging affective processing circuits.

The between group differences do support that the GAD group showed a predisposition to either the engagement or exacerbated expression of the affective decision making system than did controls. The decision making regarding game choice was more polarized, with control participants playing the pattern game 52% of the time on average, while the GAD group played it 69% of the time average. This reflects a less balanced behavioral response and possibly the behavioral inflexibility of disordered anxiety (LeDoux, 1996, Ninan, 1999). This is supported by the personality results, with the GAD group showing significantly higher behavioral suppression, supporting general avoidance in this population. The lack of significant differences between seeking scores and the lower maintenance scores than controls, suggest that this group does not differ in the seeking of or responsivity to rewards. The implications of this in interpreting the above results suggest an overall difference from the anhedonia and reward system dysfunction suggested previously for depressed populations. This suggests that the reward system functions appropriately at the surface motivational level in the GAD participants and that these participants desire an overall change in behavioral state, but that seeking behaviors are suppressed due to anxiety. While these were not found to be directly related to the psychophysiological data in this study, the strength of these differences support their inclusion in future research on the neuropsychology of anxiety.

Similar to previous results in our laboratory (Highsmith et al., in preparation), reduced errors on a Stroop like task were found, with better overall performance for higher levels of anxiety. This was thought to reflect greater attention resource allocation to prevent errors and negative feedback, the finding for the D-KEFS CWIT was only found for errors. The fewer errors for the GAD group could be due to greater vigilance and attentional resources recruited to avoid these errors. However, the overall time for completion was not significantly different between groups, as was the case in the previous research task with subclinical samples. These results may suggest a curvilinear relationship between anxiety and Stroop-like task performance, with peak performance for the higher end of the subclinical anxiety group, which would be represented in the control group for the current study. If the proposed tenet of greater vigilance for the GAD group were true, one would expect some general performance improvements on other tests, however, none were found. The only other neuropsychological test difference found for these groups was significantly faster performance on the TMT part A for the GAD group. These findings are difficult to reconcile with the previous CWIT findings, in that faster performance on the TMT would make errors more likely, even though no sequencing errors were noted for any of the young-adult, undergraduate participants.

Conclusion and Directions for Future Research

The final investigation in this work was undertaken to identify the utility of using cognitive neuroscience and electrophysiological techniques to identify information processing biases regarding reward feedback predicted by the overall CBT etiological model of mental illness. The cognitive model proposes those with psychological disorders would demonstrate biases in how they perceive situations, affectively respond to those situations, and process information during evaluation of these situations (Beck, 2008), some of which is supported in this study. Overall, this study supports that the feedback negativity may be a useful physiological correlate of information processing biases in anxiety disorders, as these tasks elicited significant differences in cingulate cortex error responding between GAD and normal control groups in reaction to positive and negative feedback (FN amplitude).

There also appeared to be differences in how the overall hybrid task was perceived, with group differences suggestive of greater focus on monetary reward versus reward frequency from the behavioral results of game choices through the GAD group demonstrating some avoidance of the game with the higher loss-win ratio, suggesting different attentional focus for the groups.

However, the specific perceptions of the games were not collected, preventing determining the focus of the groups. Future research should collect data regarding participant subjective decision making factors, including self-report of believed reasons for selecting games within commission of the task.

The affective responses to the tasks were not adequately measured in the study, precluding specific investigation of this aspect of the model. One of the limitations of the current study concerns the timing of HRV measurements. This suggests that future studies involving similar tasks should be extended in time to allow a 5 minute recording window for HRV recording, to allow Group by Task ANOVAs to help determine affective response differences and further evidence of the engagement of attentional set.

Findings do support the feasibility of a larger scale study investigating electrophysiological markers of cognitive control in anxiety disorders. The limitations of the current study due to sample size made interpreting personality and neuropsychological test results difficult, as there was not sufficient power to make credulous interpretations of insignificant findings. Future research should ensure larger scale studies with adequate numbers of participants to allow better determination of the role of executive functioning in neurophysiological response to the tasks and allow for investigation of gender differences. Finally, the groups utilized in the current study represent vastly different levels of self-reported anxiety and reduces the generalizability of any findings. With the possibility that the advertised recruitment script resulted in a selection of individuals who identified themselves as “clinical” might have resulted in the widely separate trait anxiety scores not reflective of known performance for clinical anxiety samples. Future research may address this issue by conducting larger scale initial screenings to identify a broad level of anxiety. In addition, future studies should aim to investigate these relationships in samples from a greater variety of ages, education levels, and cultural/ethnic backgrounds.

Chapter 6: Conspectus

This series of studies provides support for including both neuropsychological and personality data in the study of neurophysiological information processing in anxiety disorders. Perhaps the most important finding of these studies is that of the differential engagement of the cognitive and affective processing systems for the pattern learning and gambling tasks. This holds important implications for the use of gambling tasks in the study of the feedback negativity, in that previous research looking for evidence of cognitive determination of reward probabilities and reward expectation might have actually engaged higher levels of affective information processing and less cognitive control. Thus, the activity of the FN in these studies might not be an equivalent ERP component to those elicited in other, more cognitively engaging, tasks. Also, there were gender differences in the relative engagement of these systems, suggesting the need for future studies using affectively engaging tasks to consider gender effects.

From the perspective of the personality data, the two theoretical meta-factors of Plasticity (β) and Stability (α) were not found when including self-report organismic behaviors regulating approaching opportunities and avoiding threats, as well as perceived emotional tone along the positive and affective dimensions. The yielded three-factor model makes intrinsic sense from a behavioral perspective in that approach behaviors and avoidance behaviors exist, but might only be engaged in certain situations, while neither might be engaged at other times. The overall personality model espoused by Gray and McNaughton (2000) suggests that the lack of action results from a balance of the approach and avoidance systems (BAS, BIS, and FFFS). However, this supposes a focus on external motivational factors, and was originally designed to account for animal behavior. Should an organism with the cognitive complexity of humans approach behavioral decision making, it is possible that additional factors influence behavior. In the case of the Maintenance component identified in these studies, it suggests that there was another factor than approach and avoidance. This factor is roughly equivalent to contentment and supposes that an individualized homeostatic state (for appetitive motivation) has been reached and there is no internal drive to seek or avoid activities.

The Reinforcement Sensitivity Theory (RST) approaches this behavioral regulation from a bottom-up approach with the systems mentioned previously. As previously reviewed, the BAS is linked to the ascending dopaminergic system from the ventral tegmental area and substantia nigra to the basal ganglia (Depue, Iacono, Rosenzweig, & Porter, 1989; Depue, Luciana, Arbisi, Collins, & Leon, 1994; Gray, 1990), the FFFS is linked with the septo-hippocampal system, amygdala, medial hypothalamus, and central grey (Gray, 1990), and the BIS is linked with the serotonergic projections from the raphe nucleus to the septo-hippocampal system (Gray, 1982), amygdala (Kagan, Snidman, & Arcus, 1992), and noradrenergic mediated fibers to the locus coeruleus (Cloninger, 1987; Depue et al., 1989). This theory supposes the primacy of emotion laden, bottom up, processing, as reactionary tendencies to move the entire body toward or away from stimuli, beginning with an appraisal system that evaluates internal and external stimuli, with the cognitive decision making processes being recruited by the affective system (Damasio, 1999). From the more global perspective of affective information processing, the overall salience of the stimulus and the emotional context is important to processing, including top-down information regarding planning and expectancies. Perhaps this planning and expectancy information, as expressed by top-down, prefrontal executive output, can inhibit the behavioral output of the bottom-up BIS, BAS, and FFFS systems, and is experienced as contentment and low drive to either seek or avoid stimuli.

There is also evidence that frontal lobes could provide expectancy information directly to the cingulate in a top-down manner (Vogt et al., 1995), through direct coding of reward and outcome expectancy (Glascher, Hampton, & O'Doherty, 2009; Hampton et al., 2007; Knutson & Cooper, 2005; Knutson et al., 2005; Knutson & Wimmer, 2007), and reward sensitivity biases in the prefrontal and orbitofrontal cortices (Pizzagalli, Sherwood, Henriques, & Davidson, 2005). When related directly to ACC feedback processing, this top-down expectancy information could also suggest that the FN may express error and conflict processing by comparing prefrontal outcome expectancies, and not depend solely on reward related input from the mesolimbic dopamine system, (Baddeley, 1986; Georgopoulos et al., 2000; Luria & Pribram, 1973). This could account for the differences between the groups, with the increased FN for the GAD group being related to the lower Maintenance scores and less top-down regulation of mesolimbic reward related outcome processing, coupled with higher Suppression scores and higher amygdalar negative feedback reactivity.

From the perspective of neurocognitive functioning, results suggest little utility in the computed measures of executive functioning in identifying attentional set or predicting feedback processing for a normal sample. Due to power limitations, the utility in the clinical sample remains unknown. The characterization of the tests utilized in these studies are largely more closely related to the cold, prefrontal cortex related executive functions and not the hot, orbitofrontal executive functions. Future research should utilize quantification of reward learning ability through tasks such as the Iowa Gambling Task to relate learning ability to FN responses. Another possibility is that the task utilized in the current line of research is not sufficiently cognitively engaging and does not require a significant amount of cognitive resources to complete. Perhaps use of a more cognitively engaging task would result in greater utilization of these resources and more utility in using neurocognitive measures to relate to feedback processing.

Overall, the finding of the behavioral and FN group differences in these tasks supports the concept of information processing differences in these groups and the deficits in cognitive control in the anxiety disorders (Etkin, Prater, Hoeft, Menon, & Schatzberg, 2010; Osinsky, Alexander, Gebhardt, & Hennig, 2010). While the methodological issues discussed previously prevented specific determination of the neurocognitive and gambling task response information to these differences, the findings do support the use of the FN as a biomarker of information processing biases in Generalized Anxiety Disorder.

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Appendix A

IRB Approvals

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
4N-70 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** · **www.ecu.edu/irb**

Notification of Exempt Certification

From:	Social/Behavioral IRB
To:	Jonathan Highsmith
CC:	Daniel Everhart Jonathan Highsmith
Date:	11/12/2012
Re:	UMCIRB 12-002072 Factor Analysis of Personality and Appetitive Motivation Measures

I am pleased to inform you that your research submission has been certified as exempt on 11/12/2012. This study is eligible for Exempt Certification under category #2.

It is your responsibility to ensure that this research is conducted in the manner reported in your application and/or protocol, as well as being consistent with the ethical principles of the Belmont Report and your profession.

This research study does not require any additional interaction with the UMCIRB unless there are proposed changes to this study. Any change, prior to implementing that change, must be submitted to the UMCIRB for review and approval. The UMCIRB will determine if the change impacts the eligibility of the research for exempt status. If more substantive review is required, you will be notified within five business days.

The UMCIRB office will hold your exemption application for a period of five years from the date of this letter. If you wish to continue this protocol beyond this period, you will need to submit an Exemption Certification request at least 30 days before the end of the five year period.

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

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Notification of Initial Approval: Expedited

From: Social/Behavioral IRB
To: Jonathan Highsmith
CC: Daniel Everhart
Date: 1/16/2013
Re: UMCIRB 12-002097
Elicitation of Cognitive and Affective Engagement in Reward Learning Tasks

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) is for the period of 1/16/2013 to 1/15/2014. The research study is eligible for review under expedited category #4. The Chairperson (or designee) deemed this study no more than minimal risk.
Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The Investigator must adhere to all reporting requirements for this study.

The approval includes the following items:

Name	Description
Debriefing Plan | History	Additional Items
Dissertation Proposal Document | History	Study Protocol or Grant Application
Informed Consent Elicitation Study | History	Consent Forms
Online Consent Paragraph 1-5-13.doc | History	Recruitment Documents/Scripts
Participant Information form.doc | History	Surveys and Questionnaires
South Oaks Gambling Screen | History	Surveys and Questionnaires

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

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Notification of Initial Approval: Expedited

From:	Social/Behavioral IRB
To:	Jonathan Highsmith
CC:	Daniel Everhart
Date:	3/11/2013
Re:	UMCIRB 13-000412 Neuropsychological and Personality Correlates of Physiological Measures of Cognitive and Affective Control

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) is for the period of 3/11/2013 to 3/10/2014. The research study is eligible for review under expedited categories #4 and #7. The Chairperson (or designee) deemed this study no more than minimal risk.

Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The Investigator must adhere to all reporting requirements for this study.
The approval includes the following items:

Name	Description
ADIS-IV.docx | History	Interview/Focus Group Scripts/Questions
Beck Depression Inventory-II (pg 2-3), not MDAQ | History	Surveys and Questionnaires
BISBAS.doc | History	Surveys and Questionnaires
Dissertation Proposal Document | History	Study Protocol or Grant Application
Informed Consent Highsmith Dissertation Experiement 3-4.doc | History	Consent Forms
Mini-IPIP.doc | History	Surveys and Questionnaires
Online Recruitment Paragraph | History	Recruitment Documents/Scripts
PANAS.doc | History	Surveys and Questionnaires
Participant Debriefing Normal Control | History	Additional Items
Participant Debriefing Script Anxiety Group.docx | History	Additional Items

Participant Debriefing Script Other Disorder Group.docx | History	Additional Items
Participant Information form.doc | History	Surveys and Questionnaires
South Oaks Gambling Screen.pdf | History	Surveys and Questionnaires
STAI-AMS.pdf | History	Surveys and Questionnaires

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00003781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418 IRB00004973

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Notification of Amendment Approval

From:	Social/Behavioral IRB
To:	Jonathan Highsmith
CC:	Daniel Everhart Jonathan Highsmith
Date:	6/4/2013
Re:	Ame1_UMCIRB 13-000412 UMCIRB 13-000412 Neuropsychological and Personality Correlates of Physiological Measures of Cognitive and Affective Control

Your Amendment has been reviewed and approved using expedited review for the period of 6/4/2013 to 3/10/2014. It was the determination of the UMCIRB Chairperson (or designee) that this revision does not impact the overall risk/benefit ratio of the study and is appropriate for the population and procedures proposed.

Please note that any further changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. A continuing or final review must be submitted to the UMCIRB prior to the date of study expiration. The investigator must adhere to all reporting requirements for this study.

Approved consent documents with the IRB approval date stamped on the document should be used to consent participants (consent documents with the IRB approval date stamp are found under the Documents tab in the study workspace).

The approval includes the following items:

Document	Description
Informed Consent Anxiety Focused 5-1713(0.01)	Consent Forms
Recruitment Flyer(0.01)	Recruitment Documents/Scripts

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

Recruitment Script (Chapter 5)

Anxiety Research Study Opportunity

Jonathan Highsmith, M.A., a doctoral candidate in clinical health psychology at East Carolina, is recruiting participants for a research study titled " *Neuropsychological and Personality Correlates of Physiological Measures of Cognitive and Affective Control"*. The goal is to recruit 29 undergraduate participants with a high level of anxiety and worry about a lot of different parts of their lives that is causing them distress and/or difficulties. It is hoped that this study will assist us to better understand the relationships between anxiety symptoms, cognitive ability, and individual differences in personality.

The first task will require you to complete online personality measures. Those that meet screening criteria will be invited to the cognitive neuroscience laboratory in the Rawl building on ECU's main campus to complete a diagnostic interview to determine eligibility to participate. Those eligible will be asked to complete neuropsychological tests, answer brief measures of current mood and previous gambling behavior, and complete computer based tasks while electroencephalographic (EEG) recordings are taken. The computer tasks will include a pattern learning memory game and a simulated gambling task.

All procedures are non-invasive. Participation will take approximately *150-240* minutes to complete. If you choose to consent to participate, you will be asked to provide some demographic information, but no data or recordings will include identifiable information. Your participation in the research is voluntary. If you choose to sign up to participate, you may choose to stop at any time. There is no payment for participating, although those completing computer based tasks will have the opportunity to win performance based rewards. Please e-mail *highsmithj06@students.ecu.edu, or call 252-917-7202* for more information or the Office for Human Research Integrity (OHRI) at 252-744-2914 for questions about your rights as a research participant.

Appendix B

Psychometric Properties of Utilized Measures

Personality Measures

BIS/BAS. The four factor structure of this scale has been identified in numerous large samples of young adults, with reliability estimates varying by scale; Cronbach's alpha was reported at 0.75 for BIS, 0.65 for BAS-RR, 0.8 for BAS-D, and 0.70 for BAS-FS (Carver & White, 1994; Jorm et al., 1996). When applied to clinical samples comprised of mood and anxiety patients, scale reliability estimates remained acceptable, ranging from 0.73 to 0.82 when separated by gender and clinical group (Campbell-Sills, Liverant, & Brown, 2004).

AMS. This scale represents a unitary measure of BAS, originally developed on student samples, and reported a Cronbach's alpha at 0.83 for the final revised version in a student sample, and at 0.81 for a second student sample (Cooper et al., 2008).

STAI-Y. The original normative samples used in construction of the STAI-Y consisted primarily of student samples, with reliability estimates ranging from 0.86 to 0.95 for internal consistency coefficients and .65 to .75 for test-retest alpha coefficients (Spielberger et al., 1983). Similar findings have been reported by Ray (1984) when administered to community samples, with estimates of Cronbach's alpha at 0.84 for a city-based, general population sample and 0.91 for a rural sample.

PANAS. The PANAS was designed to measure two orthogonal mood constructs and was originally normed on student samples, but numerous variations of the scale have been created, with variations on the length of personal history considered by respondents when formulating responses. In general, reported Cronbach's alpha coefficients for these various time reference periods ranged from .86 to .90 for positive affect (.88 for the "in general" time period) and .84

to .87 for negative affect (.87 for the "in general" time period) in Watson et al. (1998). Test-retest across an 8-week interval has shown less adequate psychometric stability with estimates reported between .47 and .68 for positive affect and .39 to .71 for negative affect, although the high end of both ranges represent the "in general" time period, utilized in the current study (Watson et al., 1988).

Mini-IPIP. Recent research on the psychometric properties of the Mini-IPIP support the five factor structure of the instrument (Cooper, Smillie, & Corr, 2010), and reliability estimates have been reported consistently as acceptable according to Cronbach's alpha and ρ for each scale, including Conscientiousness, $\alpha = .65$, $\rho = .72$, Extraversion, $\alpha = .71$, $\rho = .78$, Agreeableness, $\alpha = .70$, $\rho = .78$, Intellect/Imagination, $\alpha = .65$, $\rho = .75$, and Neuroticism, $\alpha = .62$, $\rho = .68$ (Baldasaro, Shanahan, & Bauer, 2013; Donnellan et al., 2006).

Neuropsychological Measures

Specific psychometric properties of many of the utilized instruments are published in their technical manuals, and are normed and designed for use with demographic groups across the population. For many of the tests (e.g. WAIS-IV and D-KEFS), measures of psychometrics, such as reliability coefficients, vary by demographic categories and are reported separately by subtest, age, and gender in some cases. This makes determining the specific psychometric adequacy of the instruments difficult, as even a single subtest Cronbach's alpha estimates may vary widely across the age range. In addition, the nature of higher executive functioning tasks utilized in the current study are known to be prone to additional variability due to the need for very complex recruitment of cognitive resources for completion (Delis, Kramer, Kaplan, & Holdnack, 2004). The properties listed below are estimates selected for a young-adult population and are not selective for a college student sample like many of the personality measures reviewed previously, and include the measures entered into principal components analyses in this work. The reader should refer to the technical manuals for a full review.

CVLT-II. Split half reliability coefficients for immediate recall were computed for each 2 trial combination across all 5 learning trials, and these combinations were averaged, resulting in an overall high, r = .94, reliability across the total sample and identical for both genders, with .93 reported for the 16-19 age group and .89 for the 20-29 age group. A number of other split-half coefficients were computed based on splitting the test into two based on categories (r = .83 across ages), and based on words endorsed (r = .78 across ages). Test-retest scores, using cross-lagged alternate forms, were computed after a 9-49 day latency period (21 day median) to compute correlations for the immediate recall, delayed recall, recognition, and process variables. Test-retest reliability was computed as .82 for immediate recall, .81 for short delay free recall, and .88 for long delay free recall.

WAIS-IV Digit Span. The overall reliability coefficients, Cronbach's alpha, for the digit span subtest are reported as .93, although slightly lower, but still exemplary, stability is reported for the 18-19 (.92) and 20-24 (.91) age groups primarily involved in the current study. Test-retest reliability across an interval of 8-82 days is somewhat lower but still adequate, reported as .82, with a slight (0.6 SS) practice effect contributing to this reduced reliability.

TMT A & B. Test-retest reliability for Part A has shown wide variation in normal young adult samples, based on retest interval with coefficients reported between .36 to .79 for one year to 3 weeks, with similar, but somewhat improved consistency for Part B, with reported coefficients between .44 to .89 (Bornstein et al., 1987; Matarazzon et al., 1974, Dikemen et al., 1999).

COWAT. Internal consistency measures for the original Benton version of the test has been reported at 0.83 (Ruff, Light, Parker, & Levin, 1996), with identical scores reported for internal consistency for the FAS version of the test (Tombaugh et al., 1999). Internal consistency for the D-KEFS norms used for scoring in the current study are reported as .80 for the 16-19 age group and .85 for the 20-29 age group, with test retest reliability at .80 for all age groups.

Animal Fluency. Test-retest reliability following a one-month interval has shown some instability in measurement with r = .56, although practice effects were noted during the second measure that reduced overall reliability estimates. In healthy adults, semantic fluency, test-retest correlations tend to be above .70 (Bird et al., 2004).

D-KEFS Sorting. The free sorting condition used in the current study shows moderate to high reliability across age groups, with internal consistency coefficients reported as .72 for the 16-19 age group and .78 for the 20-29 age group. However, test-retest reliabilities reported for this test are modest, with coefficients only reported at .51 across ages, with large practice effects reported for younger age groups and reliability scores reported as .49 for the 8-19 age group after a 9-74 day interval.

D-KEFS Tower. Internal consistency measures on this test were computed using split-half of even-odd items, as there are only nine-items on the test. However, the items are designed for increasing difficulty, and no equivalent split-halves are possible. Coefficients are reported as .60 for the 16-19 age group and .62 for the 20-29 age group. Total achievement test-retest scores are also low, with coefficients reported at .44 for all age groups. Of note, only the total achievement score reliabilities are reported in the technical manual and none of the process scores, including the total moves score used in this study, are reported.

D-KEFS CWIT. As this test includes processing speed, internal split-half consistency on each trial would be an inaccurate measure, due to fatigue effects. As this test, has two easier and two harder conditions, comparing performance on these separate conditions results in marginal to good consistency across age groups, with coefficients reported as .75 for the 16-19 age group and .82 for the 20-29 age group. Test retest reliability after a 9-74 day interval is between .77 and .90 for ages 8-19 and between .49 and .86 for ages 20-49. The lowest values are for the word reading and inhibition/switching trials.

Appendix C

Experiment 2

Label	Mode	Duration	Window	ITI	XPOS	YPOS	Response	Type
	RESET	ALL	0	0	0	0	0	0
	GOSUB	Cognitive	0	0	0	0	0	0
	TEXT	0.00	wait	66.67	0	0	0	0
	GOSUB	Affective	0	0	0	0	0	0
	TEXT	0.00	wait	66.67	0	0	0	0
	KEY	0	0	0	0	0	0	0
	STOP	0	0	0	0	0	0	0
Cognitive	GOSUB	TrainingC	0	0	0	0	0	0
	GOSUB	RR	0	0	0	0	0	0
	GOSUB	LR	0	0	0	0	0	0
	GOSUB	RR	0	0	0	0	0	0
	GOSUB	RL	0	0	0	0	0	0
	GOSUB	LL	0	0	0	0	0	0
	GOSUB	LL	0	0	0	0	0	0
	GOSUB	LR	0	0	0	0	0	0
	GOSUB	RL	0	0	0	0	0	0
	GOSUB	RL	0	0	0	0	0	0
	GOSUB	LR	0	0	0	0	0	0
	GOSUB	LL	0	0	0	0	0	0
	GOSUB	LL	0	0	0	0	0	0
	GOSUB	RL	0	0	0	0	0	0
	GOSUB	RR	0	0	0	0	0	0
	GOSUB	LR	0	0	0	0	0	0
	GOSUB	RR	0	0	0	0	0	0
	GOSUB	LL	0	0	0	0	0	0
	GOSUB	RL	0	0	0	0	0	0
	GOSUB	RL	0	0	0	0	0	0
	GOSUB	RR	0	0	0	0	0	0
	GOSUB	LL	0	0	0	0	0	0
	GOSUB	LR	0	0	0	0	0	0
	GOSUB	RR	0	0	0	0	0	0
	GOSUB	LR	0	0	0	0	0	0
	GOSUB	LR	0	0	0	0	0	0
	GOSUB	RR	0	0	0	0	0	0

	GOSUB	LR	0	0	0	0	0	0
	GOSUB	LL	0	0	0	0	0	0
	GOSUB	RR	0	0	0	0	0	0
	GOSUB	RL	0	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
TrainingC	TEXT	0.00	wait	66.67	0	0	0	0
	GOSUB	LL	0	0	0	0	0	0
	GOSUB	RR	0	0	0	0	0	0
	RESET	3	0	0	0	0	0	0
	TEXT	0.00	wait	66.67	0	0	0	0
	RETURN	0	0	0	0	0	0	0
LL	TEXT	1000.00	0.00	1100.00	0	0	0	0
	GOSUB	Train LL	0	0	0	0	0	0
	GOSUB	Mem LL	0	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
LR	TEXT	1000.00	0.00	1100.00	0	0	0	0
	GOSUB	Train LR	0	0	0	0	0	0
	GOSUB	Mem LR	0	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
RR	TEXT	1000.00	0.00	1100.00	0	0	0	0
	GOSUB	Train RR	0	0	0	0	0	0
	GOSUB	Mem RR	0	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
RL	TEXT	1000.00	0.00	1100.00	0	0	0	0
	GOSUB	Train RL	0	0	0	0	0	0
	GOSUB	Mem RL	0	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
Train LL	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinPoint	GOSUB	LosePoint
	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinPoint	GOSUB	LosePoint
	RETURN	0	0	0	0	0	0	0
Train LR	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinPoint	GOSUB	LosePoint
	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0

	IF	RESP	0	2	GOSUB	LosePoint	GOSUB	WinPoint
	RETURN	0	0	0	0	0	0	0
Train RR	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LosePoint	GOSUB	WinPoint
	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LosePoint	GOSUB	WinPoint
	RETURN	0	0	0	0	0	0	0
Train RL	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LosePoint	GOSUB	WinPoint
	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinPoint	GOSUB	LosePoint
	RETURN	0	0	0	0	0	0	0
Mem LL	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinPoint	GOSUB	LosePoint
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinPoint	GOSUB	LosePoint
	RETURN	0	0	0	0	0	0	0
Mem LR	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinPoint	GOSUB	LosePoint
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LosePoint	GOSUB	WinPoint
	RETURN	0	0	0	0	0	0	0
Mem RR	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LosePoint	GOSUB	WinPoint
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LosePoint	GOSUB	WinPoint
	RETURN	0	0	0	0	0	0	0
Mem RL	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LosePoint	GOSUB	WinPoint
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinPoint	GOSUB	LosePoint
	RETURN	0	0	0	0	0	0	0
LosePoint	IRAND	0	1050.00	1100.00	0	0	0	0
	IMAGE	1000.00	0.00	66.67	0	0	0	2
	CDEC	3	25	0	0	0	0	0

	RETURN	0	0	0	0	0	0	0
WinPoint	IRAND	0	1050.00	1100.00	0	0	0	0
	IMAGE	1000.00	0.00	66.67	0	0	0	1
	CINC	3	25	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
Affective	GOSUB	TrainingA	0	0	0	0	0	0
	RESET	20	0	0	0	0	0	0
	CINC	20	100	0	0	0	0	0
	GOSUB	RRRL	0	0	0	0	0	0
	GOSUB	LRRL	0	0	0	0	0	0
	GOSUB	RLRL	0	0	0	0	0	0
	GOSUB	LLLR	0	0	0	0	0	0
	GOSUB	LRRL	0	0	0	0	0	0
	GOSUB	RRRR	0	0	0	0	0	0
	GOSUB	LRRL	0	0	0	0	0	0
	GOSUB	RLRL	0	0	0	0	0	0
	GOSUB	LRRL	0	0	0	0	0	0
	GOSUB	LRRL	0	0	0	0	0	0
	GOSUB	LLLR	0	0	0	0	0	0
	GOSUB	LLLR	0	0	0	0	0	0
	GOSUB	RRRL	0	0	0	0	0	0
	GOSUB	LRRL	0	0	0	0	0	0
	GOSUB	RLRL	0	0	0	0	0	0
	GOSUB	RLRL	0	0	0	0	0	0
	GOSUB	LRRL	0	0	0	0	0	0
	GOSUB	RRRR	0	0	0	0	0	0
	GOSUB	RRRL	0	0	0	0	0	0
	GOSUB	LLLR	0	0	0	0	0	0
	GOSUB	RLRL	0	0	0	0	0	0
	GOSUB	LRRL	0	0	0	0	0	0
	GOSUB	LLLR	0	0	0	0	0	0
	GOSUB	LRRL	0	0	0	0	0	0
	GOSUB	RLRL	0	0	0	0	0	0
	GOSUB	LRRL	0	0	0	0	0	0
	GOSUB	RRRL	0	0	0	0	0	0
	GOSUB	LRRL	0	0	0	0	0	0
	GOSUB	RRRL	0	0	0	0	0	0
	GOSUB	RLRL	0	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0

TrainingA	TEXT	0.00	wait	66.67	0	0	0	0
	RETURN	0	0	0	0	0	0	0
RRRR	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	RETURN	0	0	0	0	0	0	0
RRRL	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinCash	GOSUB	LoseCash
	RETURN	0	0	0	0	0	0	0
RLRL	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinCash	GOSUB	LoseCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinCash	GOSUB	LoseCash
	RETURN	0	0	0	0	0	0	0
LRRL	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinCash	GOSUB	LoseCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinCash	GOSUB	LoseCash
	RETURN	0	0	0	0	0	0	0
LLLR	IMAGE	0.00	wait	66.67	0	0	1	0

	IF	RESP	0	2	GOSUB	WinCash	GOSUB	LoseCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinCash	GOSUB	LoseCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinCash	GOSUB	LoseCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	RETURN	0	0	0	0	0	0	0
LoseCash	IRAND	0	1050.00	1100.00	0	0	0	0
	IMAGE	1000.00	0.00	66.67	0	0	0	4
	CDEC	20	25	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
WinCash	IRAND	0	1050.00	1100.00	0	0	0	0
	IMAGE	1000.00	0.00	66.67	0	0	0	3
	CINC	20	25	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0

Experiment 3

Label	*Mode*	*Duration*	*Window*	*ITI*	*XPOS*	*YPOS*	*Response*	*Type*
	RESET	ALL	0	0	0	0	0	0
	GOSUB	Affective	0	0	0	0	0	0
	TEXT	0.00	wait	66.67	0	0	0	0
	KEY	0	0	0	0	0	0	0
	GOSUB	Cognitive	0	0	0	0	0	0
	TEXT	0.00	wait	66.67	0	0	0	0
	KEY	0	0	0	0	0	0	0
	GOSUB	Hybrid	0	0	0	0	0	0
	TEXT	0.00	wait	66.67	0	0	0	0
	KEY	0	0	0	0	0	0	0
	STOP	0	0	0	0	0	0	0
Cognitive	GOSUB	TrainingC	0	0	0	0	0	0
	GOSUB	RR	0	0	0	0	0	0
	GOSUB	LR	0	0	0	0	0	0
	GOSUB	RR	0	0	0	0	0	0
	GOSUB	RL	0	0	0	0	0	0
	GOSUB	LL	0	0	0	0	0	0
	GOSUB	LL	0	0	0	0	0	0
	GOSUB	LR	0	0	0	0	0	0
	GOSUB	RL	0	0	0	0	0	0
	GOSUB	RL	0	0	0	0	0	0
	GOSUB	LR	0	0	0	0	0	0
	GOSUB	LL	0	0	0	0	0	0
	GOSUB	LL	0	0	0	0	0	0
	GOSUB	RL	0	0	0	0	0	0
	GOSUB	RR	0	0	0	0	0	0
	GOSUB	LR	0	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
TrainingC	TEXT	0.00	wait	66.67	0	0	0	0
	GOSUB	LL	0	0	0	0	0	0
	GOSUB	RR	0	0	0	0	0	0
	RESET	3	0	0	0	0	0	0
	TEXT	0.00	wait	66.67	0	0	0	0
	RETURN	0	0	0	0	0	0	0
LL	TEXT	1000.00	0.00	1100.00	0	0	0	0
	GOSUB	Train LL	0	0	0	0	0	0

	GOSUB	Train LL	0	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
LR	TEXT	1000.00	0.00	1100.00	0	0	0	0
	GOSUB	Train LR	0	0	0	0	0	0
	GOSUB	Train LR	0	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
RR	TEXT	1000.00	0.00	1100.00	0	0	0	0
	GOSUB	Train RR	0	0	0	0	0	0
	GOSUB	Train RR	0	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
RL	TEXT	1000.00	0.00	1100.00	0	0	0	0
	GOSUB	Train RL	0	0	0	0	0	0
	GOSUB	Train RL	0	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
Train LL	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinPoint	GOSUB	LosePoint
	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinPoint	GOSUB	LosePoint
	RETURN	0	0	0	0	0	0	0
Train LR	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinPoint	GOSUB	LosePoint
	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LosePoint	GOSUB	WinPoint
	RETURN	0	0	0	0	0	0	0
Train RR	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LosePoint	GOSUB	WinPoint
	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LosePoint	GOSUB	WinPoint
	RETURN	0	0	0	0	0	0	0
Train RL	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LosePoint	GOSUB	WinPoint
	IMAGE	500.00	0.00	1500.00	0	0	0	0

	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinPoint	GOSUB	LosePoint
	RETURN	0	0	0	0	0	0	0
LosePoint	IRAND	0	1050.00	1100.00	0	0	0	0
	IMAGE	1000.00	0.00	66.67	0	0	0	2
	CDEC	3	5	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
WinPoint	IRAND	0	1050.00	1100.00	0	0	0	0
	IMAGE	1000.00	0.00	66.67	0	0	0	1
	CINC	3	5	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
Affective	GOSUB	TrainingA	0	0	0	0	0	0
	RESET	20	0	0	0	0	0	0
	CINC	20	100	0	0	0	0	0
	GOSUB	LLLR	0	0	0	0	0	0
	GOSUB	LRRL	0	0	0	0	0	0
	GOSUB	RLRL	0	0	0	0	0	0
	GOSUB	LLLR	0	0	0	0	0	0
	GOSUB	LRRL	0	0	0	0	0	0
	GOSUB	RLRL	0	0	0	0	0	0
	GOSUB	LRRL	0	0	0	0	0	0
	GOSUB	RLRL	0	0	0	0	0	0
	GOSUB	LRRL	0	0	0	0	0	0
	GOSUB	LRRL	0	0	0	0	0	0
	GOSUB	LLLR	0	0	0	0	0	0
	GOSUB	LLLR	0	0	0	0	0	0
	GOSUB	RLRL	0	0	0	0	0	0
	GOSUB	LLLR	0	0	0	0	0	0
	GOSUB	RLRL	0	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
TrainingA	TEXT	0.00	wait	66.67	0	0	0	0
	RETURN	0	0	0	0	0	0	0
RLRL	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinCash	GOSUB	LoseCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	IMAGE	0.00	wait	66.67	0	0	1	0

	IF	RESP	0	2	GOSUB	WinCash	GOSUB	LoseCash
	RETURN	0	0	0	0	0	0	0
LRRL	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinCash	GOSUB	LoseCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinCash	GOSUB	LoseCash
	RETURN	0	0	0	0	0	0	0
LLLR	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinCash	GOSUB	LoseCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinCash	GOSUB	LoseCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinCash	GOSUB	LoseCash
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseCash	GOSUB	WinCash
	RETURN	0	0	0	0	0	0	0
LoseCash	IRAND	0	1050.00	1100.00	0	0	0	0
	IMAGE	1000.00	0.00	66.67	0	0	0	4
	CDEC	20	25	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
WinCash	IRAND	0	1050.00	1100.00	0	0	0	0
	IMAGE	1000.00	0.00	66.67	0	0	0	3
	CINC	20	25	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
Hybrid	TEXT	0.00	wait	66.67	0	0	0	0
	KEY	0	0	0	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	0	11
	IF	RESP	0	2	GOSUB	BLRRL	GOSUB	BonusLL
	TEXT	1000.00	0.00	1100.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	0	12
	IF	RESP	0	2	GOSUB	BonusRL	GOSUB	BLLLR
	TEXT	1000.00	0.00	1100.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	0	11
	IF	RESP	0	2	GOSUB	BLRRL	GOSUB	BonusLL
	TEXT	1000.00	0.00	1100.00	0	0	0	0

IMAGE	0.00	wait	66.67	0	0	0	12
IF	RESP	0	2	GOSUB	BonusLR	GOSUB	BRRLL
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	11
IF	RESP	0	2	GOSUB	BRRLL	GOSUB	BonusRL
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	12
IF	RESP	0	2	GOSUB	BonusRR	GOSUB	BLLLR
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	11
IF	RESP	0	2	GOSUB	BLRRL	GOSUB	BonusLL
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	12
IF	RESP	0	2	GOSUB	BonusLL	GOSUB	BRLRL
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	11
IF	RESP	0	2	GOSUB	BRLRL	GOSUB	BonusLR
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	12
IF	RESP	0	2	GOSUB	BonusRR	GOSUB	BLLLR
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	11
IF	RESP	0	2	GOSUB	BRRLL	GOSUB	BonusLL
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	12
IF	RESP	0	2	GOSUB	BonusRL	GOSUB	BLRRL
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	11
IF	RESP	0	2	GOSUB	BRRLL	GOSUB	BonusLR
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	12
IF	RESP	0	2	GOSUB	BonusRR	GOSUB	BRRLL
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	11
IF	RESP	0	2	GOSUB	BRLRL	GOSUB	BonusRR
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	12
IF	RESP	0	2	GOSUB	BonusRL	GOSUB	BLLLR
TEXT	1000.00	0.00	1100.00	0	0	0	0

IMAGE	0.00	wait	66.67	0	0	0	11
IF	RESP	0	2	GOSUB	BLLLR	GOSUB	BonusRL
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	12
IF	RESP	0	2	GOSUB	BonusLR	GOSUB	BRLRL
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	11
IF	RESP	0	2	GOSUB	BLRRL	GOSUB	BonusRR
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	12
IF	RESP	0	2	GOSUB	BonusLL	GOSUB	BLRRL
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	11
IF	RESP	0	2	GOSUB	BLLLR	GOSUB	BonusLR
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	12
IF	RESP	0	2	GOSUB	BonusLR	GOSUB	BLRRL
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	11
IF	RESP	0	2	GOSUB	BLLLR	GOSUB	BonusRR
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	12
IF	RESP	0	2	GOSUB	BonusLL	GOSUB	BRLRL
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	11
IF	RESP	0	2	GOSUB	BRRLL	GOSUB	BonusRL
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	12
IF	RESP	0	2	GOSUB	BonusRL	GOSUB	BLRRL
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	11
IF	RESP	0	2	GOSUB	BRRLL	GOSUB	BonusRR
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	12
IF	RESP	0	2	GOSUB	BonusRR	GOSUB	BLLLR
TEXT	1000.00	0.00	1100.00	0	0	0	0
IMAGE	0.00	wait	66.67	0	0	0	11
IF	RESP	0	2	GOSUB	BRLRL	GOSUB	BonusLR
TEXT	1000.00	0.00	1100.00	0	0	0	0

	IMAGE	0.00	wait	66.67	0	0	0	12
	IF	RESP	0	2	GOSUB	BonusLL	GOSUB	BLRRL
	RETURN	0	0	0	0	0	0	0
BonusLL	TEXT	1000.00	0.00	1100.00	0	0	0	0
	GOSUB	Train BLL	0	0	0	0	0	0
	GOSUB	Train BLL	0	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
BonusLR	TEXT	1000.00	0.00	1100.00	0	0	0	0
	GOSUB	Train BLR	0	0	0	0	0	0
	GOSUB	Train BLR	0	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
BonusRR	TEXT	1000.00	0.00	1100.00	0	0	0	0
	GOSUB	Train BRR	0	0	0	0	0	0
	GOSUB	Train BRR	0	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
BonusRL	TEXT	1000.00	0.00	1100.00	0	0	0	0
	GOSUB	Train BRL	0	0	0	0	0	0
	GOSUB	Train BRL	0	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
BRLRL	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseG	GOSUB	WinG
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinG	GOSUB	LoseG
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseG	GOSUB	WinG
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinG	GOSUB	LoseG
	RETURN	0	0	0	0	0	0	0
BLRRL	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinG	GOSUB	LoseG
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseG	GOSUB	WinG
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseG	GOSUB	WinG
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinG	GOSUB	LoseG
	RETURN	0	0	0	0	0	0	0
BLLLR	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinG	GOSUB	LoseG

	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinG	GOSUB	LoseG
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinG	GOSUB	LoseG
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseG	GOSUB	WinG
	RETURN	0	0	0	0	0	0	0
BRRLL	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseG	GOSUB	WinG
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseG	GOSUB	WinG
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinG	GOSUB	LoseG
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinG	GOSUB	LoseG
	RETURN	0	0	0	0	0	0	0
Train BLL	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinP	GOSUB	LoseP
	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinP	GOSUB	LoseP
	RETURN	0	0	0	0	0	0	0
Train BLR	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinP	GOSUB	LoseP
	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseP	GOSUB	WinP
	RETURN	0	0	0	0	0	0	0
Train BRR	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseP	GOSUB	WinP
	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	LoseP	GOSUB	WinP
	RETURN	0	0	0	0	0	0	0
Train BRL	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0

	IF	RESP	0	2	GOSUB	LoseP	GOSUB	WinP
	IMAGE	500.00	0.00	1500.00	0	0	0	0
	IMAGE	0.00	wait	66.67	0	0	1	0
	IF	RESP	0	2	GOSUB	WinP	GOSUB	LoseP
	RETURN	0	0	0	0	0	0	0
WinP	IRAND	0	1050.00	1100.00	0	0	0	0
	IMAGE	1000.00	0.00	66.67	0	0	0	5
	CINC	20	5	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
WinG	IRAND	0	1050.00	1100.00	0	0	0	0
	IMAGE	1000.00	0.00	66.67	0	0	0	7
	CINC	20	10	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
LoseP	IRAND	0	1050.00	1100.00	0	0	0	0
	IMAGE	1000.00	0.00	66.67	0	0	0	6
	CDEC	20	5	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0
LoseG	IRAND	0	1050.00	1100.00	0	0	0	0
	IMAGE	1000.00	0.00	66.67	0	0	0	9
	CDEC	20	4	0	0	0	0	0
	RETURN	0	0	0	0	0	0	0